Distributed Generation

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ELECTRIC POWER RESEARCH INSTITUTE

EPRI JOURNAL

APRIL/MAY
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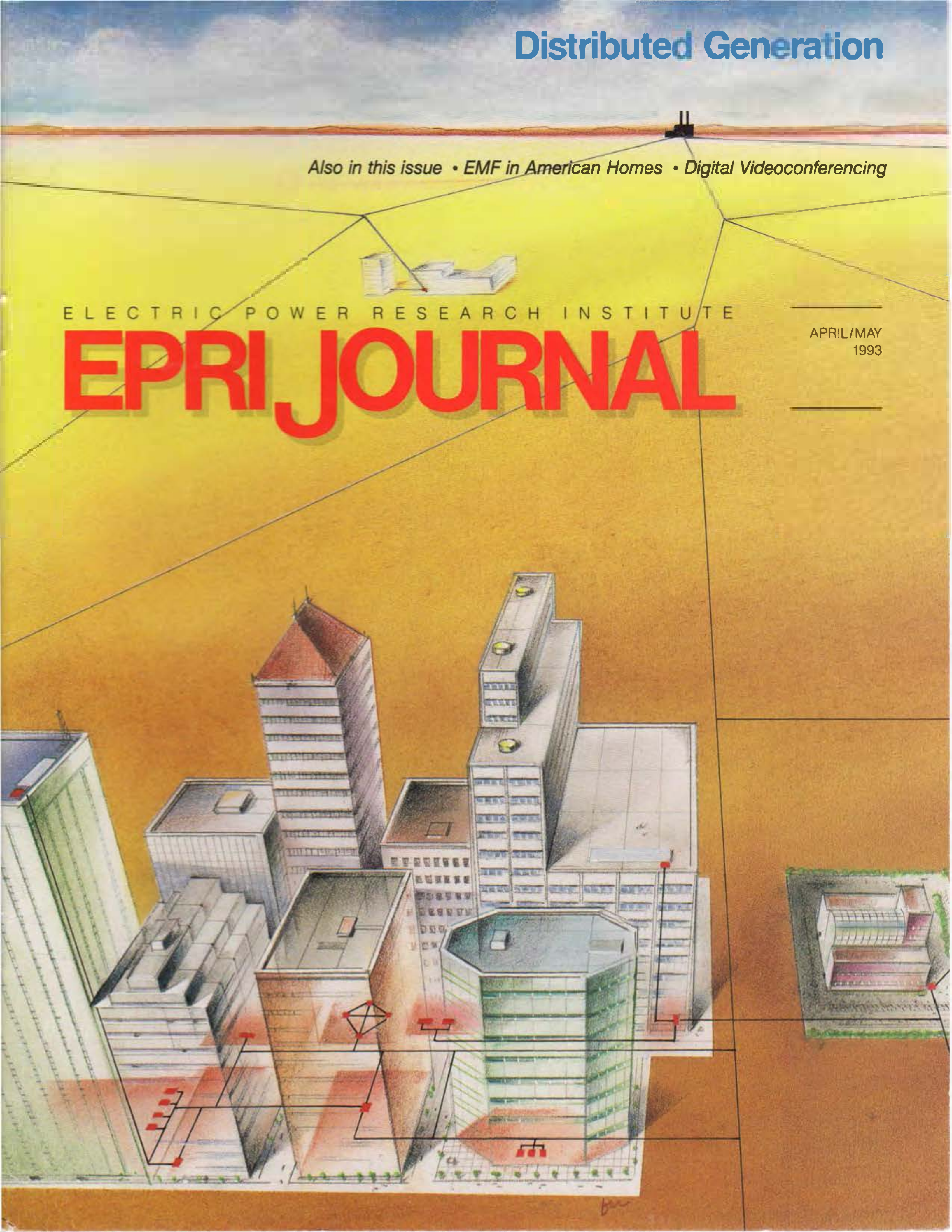

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Cover: The distributed generation concept would supplement central station power plants with modular generation units placed nearer to customers, right in the distribution system.

FROM THE EDITOR

In this issue we are launching a number of design and content changes that we feel will enhance the value of the *Journal* to our readers. The most important change is the addition of four new departments that focus on specific stages of EPRI's work, from basic science and the inception of new projects to the transfer and use of research results. Through these sections we will be broadening the *Journal's* coverage of EPRI's activities and delivering this information in formats that are shorter, more interesting, and easier to use.

Discovery, reporting mainly on work managed by EPRI's Office of Exploratory & Applied Research, focuses on scientific cross-fertilization and advanced concepts that can have far-reaching effects on the industry and society. The **Products** section catalogs R&D deliverables now available to EPRI members and their customers. Spanning a broad range that includes hardware, software, end-use appliances, procedural guidelines, and scientific information, these products address real needs of current importance to the industry.

By providing an early look at new research initiatives, **Project Startups** highlights opportunities for member utilities to become involved with projects of interest at the earliest stages of inquiry. The results of such involvement can be seen in our new **In the Field** department, which describes cooperative work with member hosts and the outcomes of applying EPRI's science and technology on utility systems.

Two other departments will be revamped and cycled in and out of later *Journal* issues: **Tech Transfer News**, which focuses on efforts to increase the effectiveness of the technology transfer process, and **At the Institute**, a section dealing with EPRI's staff and operations.

We hope that the new additions will give you better access to the entire range of the Institute's activities and help you take the fullest advantage of its R&D results. If you have comments or suggestions about how the *EPRI Journal* can better serve your needs, please let us know.

David Dietrich

David Dietrich
Editor

EPRI JOURNAL

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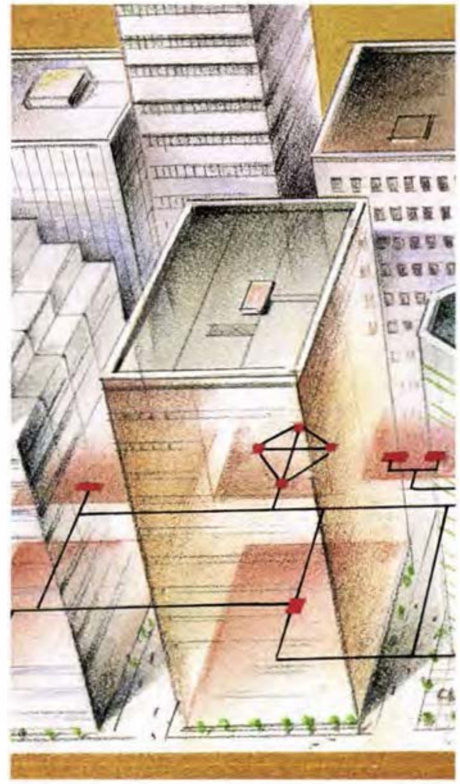

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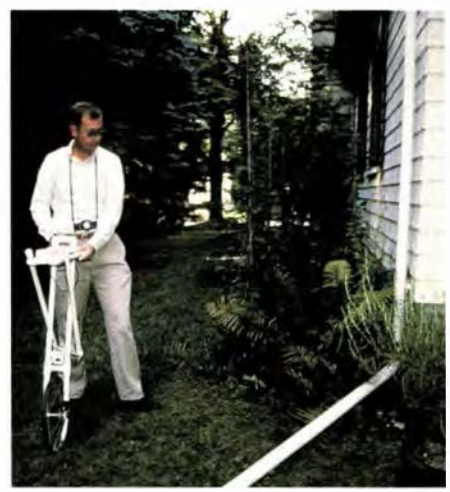

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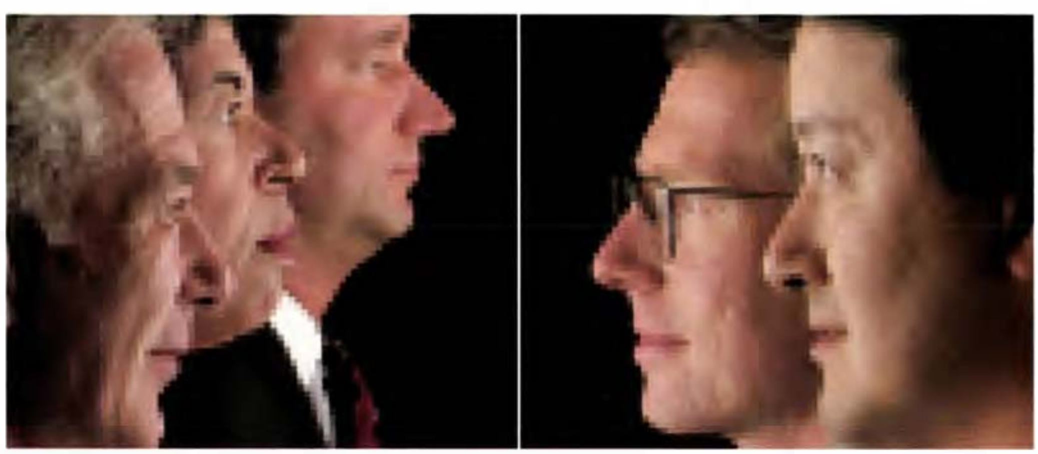

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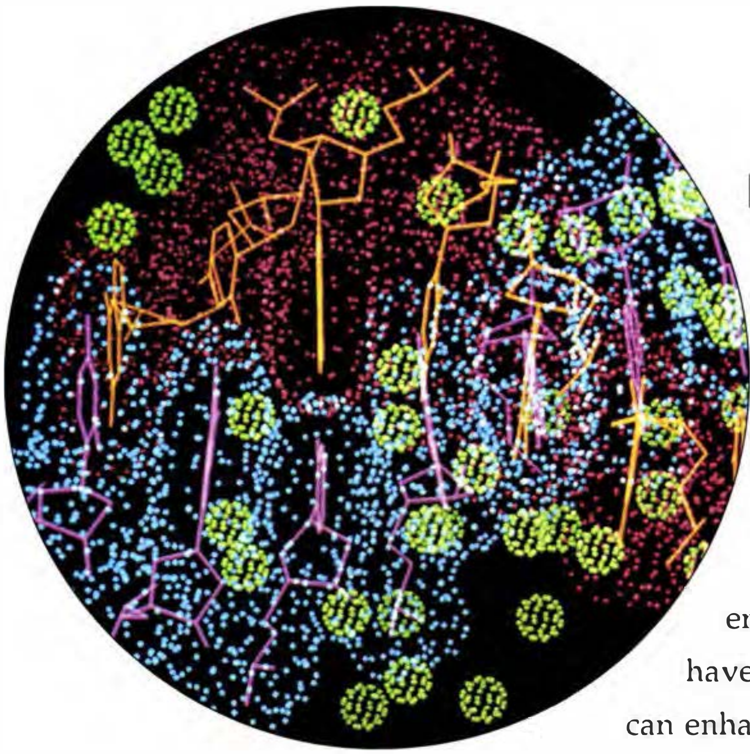
Genetic Inducers Enhance Toxic Waste Cleanup



The emerging science of genetic ecology seeks to genetically amplify the activity of naturally occurring microorganisms in order to break toxic substances at contaminated sites down into harmless forms. This effort has usually involved modifying environmental conditions—for example, adding nutrients or oxygenating the soil. Now researchers have discovered that certain innocuous substances can enhance microbial detoxification by increasing the abundance and activity of specific gene sequences.

The cost of cleaning up environmental contamination would be greatly reduced if naturally occurring microorganisms could be stimulated to do the job. Microbial detoxification processes are controlled by sequences of genes, called operons, which operate as units. Genetic ecologists first determine which useful operons are present in bacteria (or other microorganisms) at a site and then seek ways to amplify their effects. The addition of inducer compounds increases the effectiveness of the genetic ecology approach by stimulating the activity of the targeted operons.

The initial work on genetic inducers has focused on operons that control the breakdown of naphthalene—one of the toxic substances commonly found at old town-gas waste dumps. The activity of these operons is controlled by a regulatory gene whose functioning depends on the presence of salicylate, a harmless intermediate product of naphthalene degradation.

EPRI-sponsored researchers at the University of California, Irvine, found that adding specific amounts of salicylate to samples of contaminated soil greatly increased the naphthalene-destroying potential of the bacteria in the samples. The addition of salicylate led to a severalfold increase in the density and activity of the bacterial operons responsible for naphthalene degradation and also helped sustain the bacterial population.

The implications of this discovery are far-reaching, according to EPRI research manager Robert Goldstein: "Inducers give us the ability, for the first time, to control specific microbial decontamination processes at the molecular level. Many degradable toxic compounds produce harmless intermediates that potentially could be used as inducers, so this technique could have wide applicability. We are seeking other inducers in the laboratory, and we hope to begin field trials of inducers later this year. EPRI and UC Irvine have also begun the process of applying for a patent on the genetic inducer concept."

■ *For more information, contact Robert Goldstein, (415) 855-2593, or Donald Porcella, (415) 855-2723.*

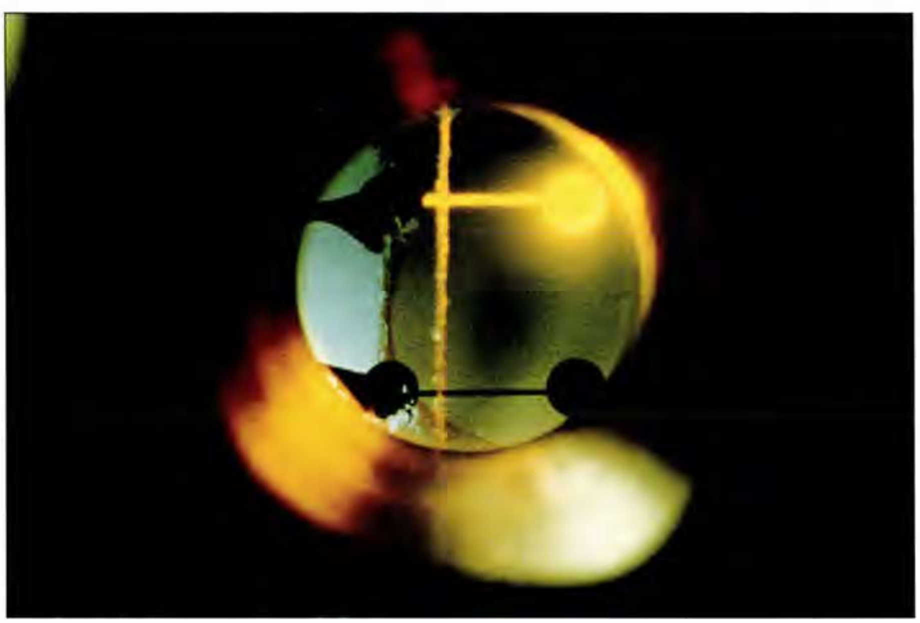
Conductive Plastics Light Up Experimental LEDs

Conductive polymers, which combine some of the electronic and optical properties of semiconductors with the mechanical characteristics of plastics, have already begun to revolutionize certain niche markets for electrical equipment, such as specialized sensors and small, high-energy batteries. Now EPRI-sponsored research is helping open up a whole new field of potential applications for these materials: they can be made to emit light and perhaps be used in photovoltaic devices and lasers.

The initial report that conductive polymers could serve as the optically active layer in a light-emitting diode (LED) came from scientists at Cambridge University in 1990. Later that year, a team at the Institute for Polymers and Organic Solids at the University of California, Santa Barbara (UCSB), confirmed the discovery, found an easier way to make polymer-based LEDs, and proposed a mechanism to explain the light emission process. EPRI's Office of Exploratory & Applied Research has been funding the Santa Barbara group's work on conductive polymer LEDs and other optical devices since early 1992.

Most LEDs today use gallium arsenide, which must be grown as a crystal on a solid substrate and is not well adapted for making large-area displays. An LED based on conductive plastics is made simply by casting a polymer film directly from a liquid solution onto a substrate, which can be flexible. This process should lend itself readily to the fabrication of large-area, patterned displays. The light emitted is bright enough to be visible under ordinary room lighting conditions, and different polymers produce different-colored light.

The polymer LED devices operate on less than 5 volts, which makes them compatible with digital electronics equipment. In addition, the light they emit is inherently polarized, which could make it simpler and less expensive to manufacture the liquid crystal displays (LCDs) commonly used in laptop computers. Current-generation LCDs require the addition of a separate polarizing layer, which reduces their luminosity.



The UCSB research on polymer LEDs is continuing to investigate the light emission mechanism involved in order to optimize efficiency. It is also focusing on the use of new polymers to obtain desired colors, the creation of uniform polymeric thin films in order to fabricate freestanding, flexible LEDs, and the stabilization of the devices.

During its research, the UCSB team also discovered other remarkable optical properties of conductive polymers. When a thin film of conductive polymer and buckminsterfullerene was exposed to light, for example, electrons migrated across the interface between the two materials. This property is key to the creation of photodetectors and photovoltaic devices. In other experiments, laser action was observed in conductive polymers still in solution; researchers hope to find ways of fabricating solid-state lasers using thin films of the polymers.

■ *For more information, contact Sy Alpert, (415) 855-2512.*

FGDPRISM for Optimum Emissions Control

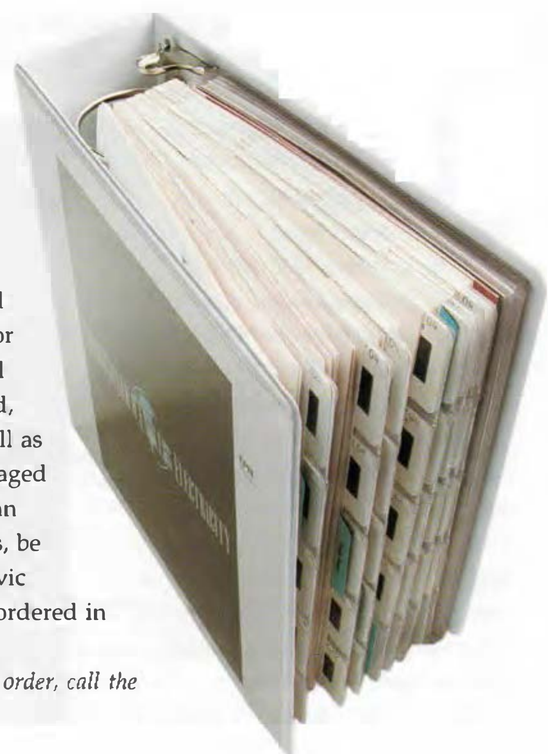
Since its release, FGDPRISM—the Flue Gas Desulfurization Process Integration and Simulation Model—has been widely praised by utilities as a valuable tool for helping them comply with the 1990 Clean Air Act Amendments. With this model, users can optimize the design and operation of flue gas desulfurization systems. Engineers can use it either to design and evaluate new FGD systems or to troubleshoot and investigate process or equipment modifications to existing systems. The model features the user-friendly EPRIGEMS interface. Attendance at an FGDPRISM training workshop is required before the program can be obtained.

For more information, contact Robert Moser, (415) 855-2277.

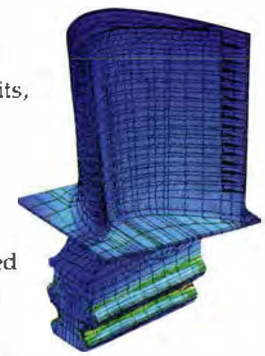
Speaker's Kit for Renewable and Storage Technologies

Utility industry speakers will be well equipped to provide an industrywide perspective on renewable energy and storage technologies with EPRI's comprehensive new speaker's kit, *Enlightened and Endless Electricity*. Developed to help utilities and others create effective presentations for nontechnical audiences, the kit offers background material and illustrative, full-color slides on five renewables—wind, solar, biomass, waste-to-energy, and hydro power—as well as on conventional and advanced storage technologies. Packaged in a three-ring binder, this product is designed so users can easily customize the material to fit their own presentations, be they for the news media, professional organizations, or civic groups. The kit includes one-page fact sheets that can be ordered in bulk for distribution to audiences.

For more information, contact Lucy Sanna, (415) 855-2732. To order, call the EPRI Distribution Center, (510) 934-4212.



BLADE: The On-line Turbine Doctor



With this sophisticated software program in their utility medical kits, engineers can diagnose the cause of turbine blade failures, evaluate proposed design modifications, and even predict how much longer existing blades will last. The BLADE (Blade Life Algorithm for Dynamic Evaluation) model is specially designed for steam turbine blade life management. Its multicolor, three-dimensional graphics make it easy for users to interpret results. An interactive tool featuring the EPRIGEMS interface, BLADE will prompt its user to enter data on the features of specific blades and the damages incurred. Results can help extend operating life and reduce maintenance costs.

For more information, contact Thomas McCloskey, (415) 855-2655. To order, call Judith Merrill at Stress Technology, Inc., (716) 424-2010.

EPRI/Frymaster Fryer

Commercial cooks will love this high-efficiency fryer developed by EPRI and Frymaster Corporation. Added insulation makes the unit 10% more energy-efficient than conventional electric models, helping cut the cost of commercial cooking. The fryer features advanced solid-state switching devices called TRIACs, which modulate the amount of energy that goes to the electric elements. A vast improvement over the electromechanical contactors in other fryers on the market today, TRIACs offer greater reliability and more precise temperature control, and they have no moving parts to wear out. The fryer's ribbon-shaped electric elements swing out of the way for easier cleaning.

For more information, contact Karl Johnson, (415) 855-2183. To order, call Frymaster Corporation, (800) 221-4583.

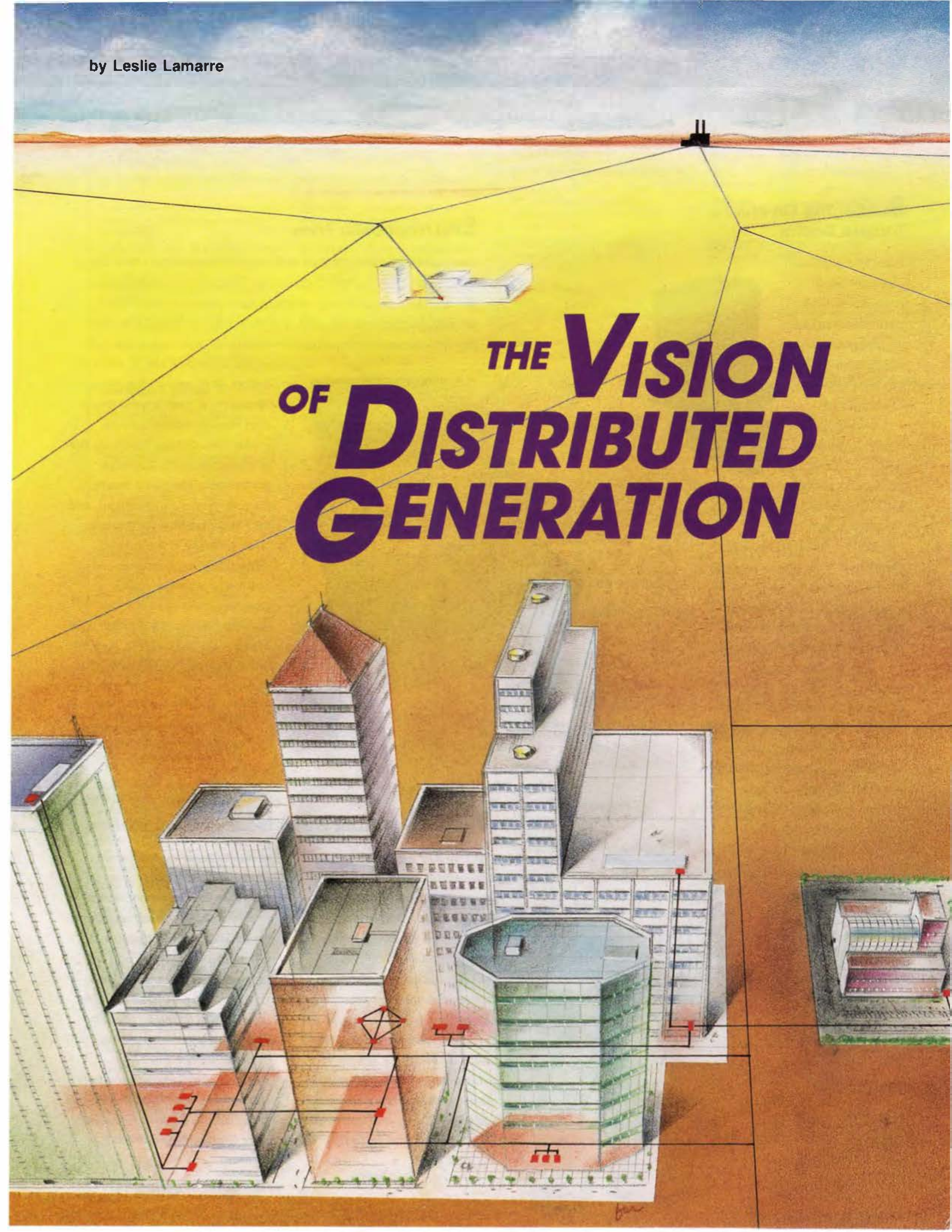
WATERMAN Plant Water Management Tool

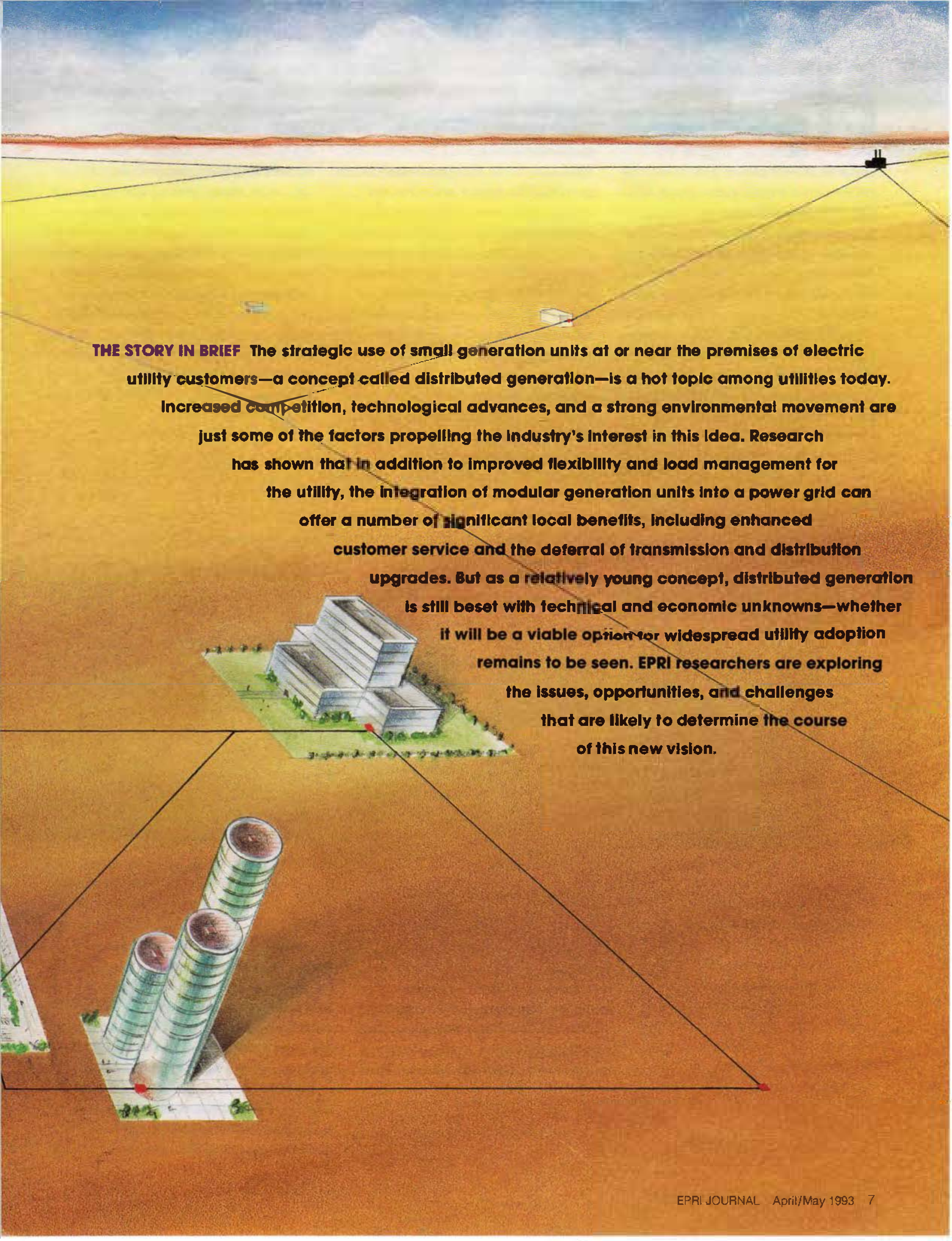
Specifically designed to meet the needs of today's environment-conscious utilities, the WATERMAN code is a critical element of the progressive utility toolbox. With WATERMAN, utilities can develop more-sophisticated water management options, such as recycling strategies, to comply with increasingly stringent wastewater discharge regulations and beat the rising costs of high-quality makeup water. Users can create comprehensive simulations of existing or planned plant water systems, calculate the impact of water system modifications on stream flows and compositions, and determine the capital and operating costs associated with these changes. Added benefits include the ability to identify operating problems or potential noncompliance discharge.

For more information, contact Michael Miller, (415) 855-2455. To order, call the Electric Power Software Center, (214) 655-8883.

by Leslie Lamarre

THE VISION OF DISTRIBUTED GENERATION





THE STORY IN BRIEF The strategic use of small generation units at or near the premises of electric utility customers—a concept called distributed generation—is a hot topic among utilities today. Increased competition, technological advances, and a strong environmental movement are just some of the factors propelling the industry's interest in this idea. Research has shown that in addition to improved flexibility and load management for the utility, the integration of modular generation units into a power grid can offer a number of significant local benefits, including enhanced customer service and the deferral of transmission and distribution upgrades. But as a relatively young concept, distributed generation is still beset with technical and economic unknowns—whether it will be a viable option for widespread utility adoption remains to be seen. EPRI researchers are exploring the issues, opportunities, and challenges that are likely to determine the course of this new vision.

Here in Silicon Valley, birthplace of the microprocessor, the tough lessons learned by IBM Corporation in the dog-eat-dog computer market linger in the minds of many business executives. The full impact of the computer giant's decision to focus on mainframe computers, losing the burgeoning personal computer market to competitors, is now becoming clear to many industries nationwide. And the electric utility industry has no desire to fall victim to similar circumstances.

Some utility industry analysts theorize that just as the market for large mainframe computers—the bulk of the computer market in the 1960s and 1970s—was invaded by the personal computer, the large central station that has served as the foundation of the utility business for the past 100 years will be supplemented by a multitude of smaller generating units located closer to utility customers. These smaller, dispersed units are called distributed generation (DG).

Heightened competition, technological advances incorporating higher-efficiency power production, an environmental movement that is gaining momentum, the availability of relatively low cost natural gas, and new legislative and regulatory initiatives are just some of the motivating factors for DG. Together, these issues are bringing about changes in the industry and the environment in which it operates that are so significant they are causing analysts to question the existing paradigm of central-station-based resource planning.

"I think distributed generation is going to be an important new trend," says Richard Balzhiser, president and CEO of EPRI. "I'm not suggesting that the central station will be displaced as a generation resource. I believe large central station plants will continue to play an important role as the backbone of utility generation, just as mainframe computers remain an important component of information networks. But technology will allow us to take advantage of a greater dispersion of generation resources for improved reliability and efficiency in the future."

Fuel cell

Gas engine

Diesel engine

THINKING SMALL Modular generation technologies, geographically dispersed but interconnected to a utility's distribution or subtransmission system, are at the heart of the distributed generation (DG) concept. Their advantages over central station power plants include relatively quick installation and lower financial risk. EPRI is exploring the potential that modular technologies offer for lowering the overall cost of electric service. Most DG units would fall in a capacity range of 100 kW to 3 MW, but some could be as large as 250 MW. (Some experts include locally targeted demand-reducing programs in their definition of distributed generation.) Shown here are some of the technologies that are considered strong candidates for implementation as distributed generation.

The scenario Balzhiser envisions is one in which distributed generation resources would supplement central station power to meet electricity demand in the small geographic regions where they are located. Industry analysts expect that DG will first take hold in a small number of applications identified as having particularly high value. Some also theorize that utilities will ultimately take the concept a step further and implement it on a systemwide basis as a tool for improving the overall economic efficiency of their systems and for enhancing customer service. This latter vision, often referred to as the distributed utility concept, offers a fundamentally different approach to resource planning that is under the intense scrutiny of researchers at EPRI and elsewhere.

"Distributed generation is a hot topic of conversation among utilities today," says Charles Jenkins, director of bulk power planning and engineering for TU Electric. "There's a lot of philosophical discussion about the future of the industry, as well as some early stages of analytical discussion as to how all of this would work. The main questions focus on how, when, and to what extent DG will be implemented and which technologies will be used, rather than on whether it will or will not happen." One gauge of the significant interest in distributed generation was the attendance of more than 100 people—including utility representatives, regulators, national laboratory researchers, and consultants—at a seminar on the topic in Berkeley, California, last December. The event was cosponsored by EPRI, Pacific Gas and Electric Company, and the Department of Energy's National Renewable Energy Laboratory.

Already, research at EPRI and elsewhere has shown that for certain niche applications, DG offers substantial benefits. Now the Institute is probing further, exploring four aspects of the concept. Through one series of projects, researchers have worked with several member utilities to develop methodologies that identify high-value applications for DG and quantify the cost-effectiveness of

Gas turbine

Batteries

Photovoltaics

these applications. In the meantime, a separate research effort is addressing the technical challenges that could arise with the implementation of DG on utility systems. A third aspect of EPRI's investigation, known as the Distributed Utility Valuation Project, is working to determine whether the systemwide implementation of DG makes sense for utilities. And finally, the Institute is examining the potential for locally targeted demand-side management programs, which appear to offer some of the same benefits as DG. Through these combined efforts, EPRI's experts aim to provide answers to what is one of the most compelling issues facing the industry today, for the widespread implementation of DG would fundamentally change the way utilities plan, operate, and conduct their business.

DG—then and now

Distributed generation can come in many forms. By EPRI's definition, it is any modular technology that is sited throughout a utility's service area—interconnected to the distribution or subtransmission system—to lower the cost of service. DG can comprise diesel and internal combustion engines, small gas turbines, fuel cells, and photovoltaics, as well as batteries and other types of storage technologies. Some utility analysts also include in their definition of distributed generation locally targeted demand-side management programs that work to reduce energy demand. Most of the DG units would offer between 100 kW and 3 MW of capacity, but some could be as large as 250 MW.

A certain amount of DG already exists in the form of both conventional technologies, such as combustion turbines and diesel engines, and advanced technologies, such as batteries, photovoltaics, and fuel cells. Many of the units serve either as on-site power generators (or cogenerators) for large industrial and commercial customers or as their backup power supplies. The precise extent to which these various forms of DG already exist is unknown, although experts surmise that the units amount to a small fraction of the national electric power capacity.

Customers installed many of the existing DG units to serve their own loads and to ensure power reliability. By contrast, the DG concept under investigation today would be initiated by utilities as a business opportunity. The aims are to lower the overall cost of serving customer loads and to enhance service quality—goals that will become even more critical to utilities as competition in the industry heats up. In fact, some utilities view DG as a means of maintaining a foothold in the generation market.

Already, regulatory reform has leveled some significant barriers to the generation market for nonutility power producers. Today these entities control over 50% of the new power capacity brought on-line annually. And the National Energy Policy Act, which became law in October of last year, inches open the floodgates of competition even further. Through an amendment to the Public Utility Holding Companies Act, the new law makes it easier for independent power producers and others to compete in the power supply market. It also increases the competitors' access to utility transmission systems by giving the Federal Energy Regulatory Commission (FERC) increased authority to order such access. Given this potential for increased transmission access, industry observers anticipate that competitors may vie for position in the retail power market, supplying electricity directly to utilities' commercial and industrial customers. (Even though the new law bars FERC from ordering such retail wheeling, it does not prohibit states from authorizing it.)

As Jeremy Bloom, manager of EPRI's Integrated Resource Planning Program, points out, increased competition may be a symptom of a more fundamental change that also encourages utility investment in smaller generation—a shift in the economics of delivering electricity to customers. The idea behind the evolution of today's vertically integrated utility, which owns and operates large central station plants and their related transmission and distribution systems, was to take advantage of the economies of scale offered by large generation plants to deliver power at a lower cost than could be achieved through the construction of smaller, separate generation units. Also encouraging the implementation of large power plants is the fact that—because separate electric loads do not rise and fall in unison—the loads on central stations are much less sharply peaked than those in individual distribution areas.

But these forces may no longer be such a dominant influence in generation planning. According to Bloom, who is coordinating research on the distributed utility concept, "Today the economies for utility systems may be shifting from economies of scale to economies of mass production." Bloom notes that the cost of conventional DG technologies, such as aeroderivative gas turbines, has declined significantly in recent years as the high-volume production of these units for use in aircraft has led to technological advances that have improved both their cost and performance. By contrast, many of the large central station plants must be custom-designed for each utility site.

Another factor making smaller generation more attractive these days is that electricity demand is no longer growing as rapidly and as predictably as it once was. In contrast to the average 7.7% annual demand growth of the 1960s, which was conducive to building big plants that could accommodate the robust market, demand growth now averages 1.6% annually. In this business environment, building large generation plants can saddle utilities with excess capacity, posing a great financial risk in the event that projected growth does not materialize.

Researchers believe that DG could provide utilities with an effective means of responding to these changes. But as Bloom points out, the widespread, strategic implementation of modular units in utilities' distribution areas requires a significant shift in utility practice. "The distributed utility concept is a radical reversal of principles that have governed the industry for most of its

CUSTOMER SERVICE **Small generating units located at or near customer facilities can improve service reliability, ensuring a continuous flow of power regardless of disturbances or outages on the utility grid. Some utilities are exploring the idea of integrating these units into their systems to enhance service to specific customers while improving the overall cost-effectiveness of the utility system. Customers like hospitals—for whom power quality can literally be an issue of life or death—are already expressing great interest in this type of service.**

history," he says. "Because its implications are so big, the idea needs to be examined thoroughly."

Strategic benefits

DG has the potential to offer utilities a number of strategic advantages, which EPRI researchers are now studying. One idea is that the modular units could be used throughout utilities' distribution areas to serve growing local peak loads, deferring the need to increase the capacity of transmission and distribution facilities. This is of great interest to utilities, particularly since T&D expenses are on the rise.

As Joe Iannucci, distributed utility program manager for Pacific Gas and Electric, points out, "It used to be that utilities would spend 25¢ on T&D compared with $1 on generation. Now they spend roughly $1.50 on T&D compared with $1 on generation." Today T&D actually represents more than 67% of utilities' total annual capital expenditures. And in the country's most capital-intensive industry, that is a lot of money—some $16 billion last year. While this trend in part reflects the low level of utility spending on new generation in recent years, it could become a permanent condition as independent power producers become more significant players in the generation market.

The cost of T&D investments and the value of deferring them could further increase as it becomes more difficult to site new T&D facilities. One factor contributing to the difficulties is rising public concern about electric and magnetic fields, which is already leading to pressure to install an increasing number of new distribution lines underground.

Although the value of DG in deferring T&D investments has yet to be demonstrated, some utility researchers are eyeing DG primarily from this perspective. According to Carl Weinberg, manager of R&D at Pacific Gas and Electric, "I think of it more as an enhancement to the distribution system than as an enhancement to the generation system. Its major role will not be in terms of electricity production but rather in the efficiency of distribution systems and the asset utilization of distribution systems."

Other potential DG benefits include the modular units' relatively quick installation and their lower financial risk, compared with large central station plants. Also, DG technologies based on renewable energy sources, such as photovoltaics, could provide fuel diversity. And given mounting public opposition to the siting of large generating facilities, the small DG modules may present more-acceptable alternatives.

Many DG technologies also release fewer emissions than conventional power plants, and for this reason they are already encouraged through federal laws. For instance, the Clean Air Act Amendments of 1990 limit the emissions of sulfur dioxide and nitrogen oxides that utilities are allowed to produce, encouraging the implementation of such low-emission technologies as solar power and fuel cells. And the recent National Energy Policy Act provides a 10% investment tax credit for solar power. (A 1.5¢/kWh production incentive is offered for wind turbines, but this technology is expected to have limited application in DG.) The act also encourages the use of demand-side management through the establishment of new ratemaking standards.

While the jury is still out on the full extent of DG's potential, researchers at Pacific Gas and Electric are among those who are already convinced that utilities can benefit from the strategic advantages of these modular technologies. In fact, PG&E recently installed a 500-kW photovoltaic demonstration system to serve a peak load in an area near Fresno, California. Construction on this installation began last October, and the unit is expected to be fully operational by the end of May. It was implemented primarily to verify the hypothesis that DG can delay the anticipated T&D upgrades that would be required to handle growth in the vicinity of the utility's Kerman substation. According to Iannucci of PG&E, the system represents the nation's first photovoltaic application of DG to defer T&D upgrades.

Ongoing technological advances are helping to propel other utilities' optimism about the potential of DG. The cost of solar-generated power has come down significantly in the past decade, from $1/kWh to 35–40¢/kWh. And utility-scale battery systems are on the threshold of commercial availability. The development of fuel cells, which convert fuels into electricity without combustion (and hence with very low emissions), is also progressing steadily; phosphoric acid fuel cells are already in operation commercially at several natural gas companies in the United States and at the sites of some utility customers in Japan. EPRI will be sponsoring a demonstration of the more advanced 2-MW carbonate fuel cell in 1995. In the meantime, small and medium-sized combustion turbines coming off the factory line today cost less and are much more sophisticated, smaller in scale, and more efficient than those of the past.

Customer service

Contributing to the attractiveness of DG is the fact that utility customers stand to benefit directly from the technology. In many cases, the smaller, locally sited units could allow utilities to meet customer needs better. For instance, DG units in the form of on-site generators owned and operated by the utility could help improve reliability for large commercial and industrial customers. And as technology advances, researchers say, more opportunities will arise to provide tailored energy services to meet customer needs.

Some utilities have begun to explore the potential advantages DG can offer for improved customer service. For instance, Niagara Mohawk Power Corporation is studying the feasibility of installing up to 15 MW of gas-fired and diesel-fired generators along a 100-mile stretch of transmission line to provide backup power in the event of outages. According to John Leana, a corporate planner for Niagara Mohawk, this 46-kV line traverses an environmentally sensitive, sparsely populated area in New York's Adirondack State Park. As a result of aging transmission facilities and restricted tree trimming, the customers—the majority of whom are residential—endure many outages each year. "It's been very difficult to provide reasonable service reliability to this area in the past because of the high cost per customer to upgrade the line," Leana says.

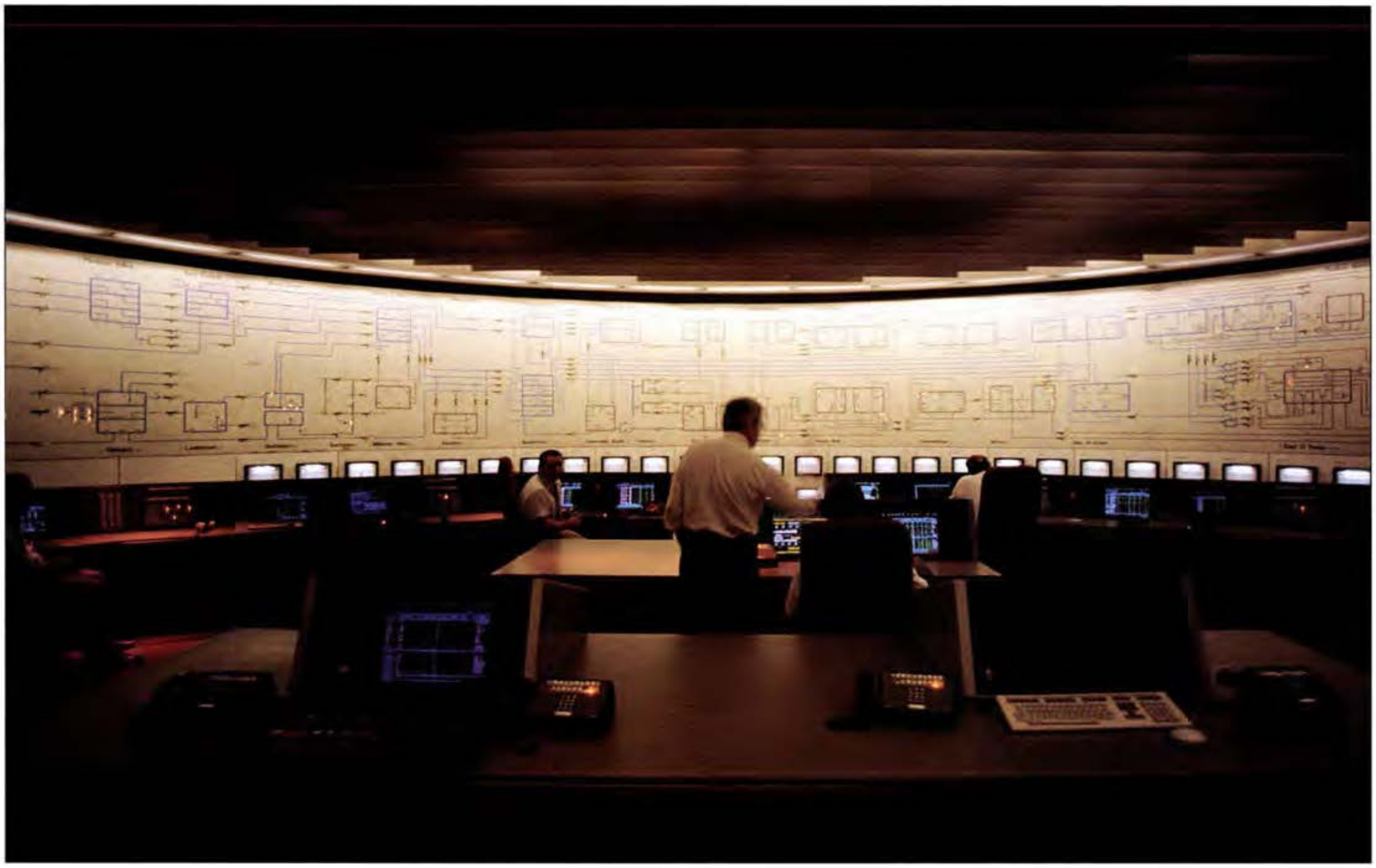
Installing a 14.5-mile 46-kV line that would provide a backup for the existing line would cost about $15 million. Leana says his utility is investigating the possible integration of demand-side management with the small gas and diesel generators as an alternative. "With the upward pressure on rates, I think customers are looking at other alternatives, which include self-generation. We aren't the only utility keeping an open mind about distributed generation. With the changes in regulatory policy regarding independent generation and now transmission access, I think utilities are very sensitive to competition. And distributed generation may provide utilities with the opportunity to retain market share and be responsive to their customers' needs."

Indeed, observes EPRI's Stephen Chapel, a manager for economic analysis, "The feeling of some in the industry is that if utilities don't offer these kinds of services, independent power producers will."

Some utilities have already implemented DG as a result of competition. For instance, a hospital in the service territory of Northern States Power Company (NSP) was experiencing some power quality problems and was in need of more-reliable electric service. The hospital received a proposal from a firm that wanted to sell it a diesel unit for self-generation. But NSP made a counteroffer to install an on-site 4-MW generator that it would own and service. The hospital accepted and agreed to terms that allow the utility to tap the unit to supply power to the grid during periods of peak demand. The unit was installed late last year.

"This was the first time something like this happened at our utility," says Benjamin Ewers, director of corporate strategy for NSP. "And we're pretty low-cost, with commercial rates in the 3–4¢/kWh range. I can imagine that utilities on the East and West coasts, where rates are at least double this amount, will feel even more of this pressure." He says his utility has compiled a list of about 25 large customers in need of highly reliable service who might be interested in similar arrangements. "The potential impact is very significant because anyone can make these small generation units—just like personal computers."

Ewers anticipates that this type of competition will ultimately enter the residential sector, and he says utilities should be preparing for that possibility. "Today, you can get a diesel generator



AN ISSUE OF CONTROL
At this time it is unclear what operational effects the widespread implementation of DG would have on utility systems. At the transmission level, utility dispatchers rely on sophisticated computerized systems that monitor demand, communicate with generation units, and adjust power accordingly to maintain a stable frequency of 60 Hz. But since the technology does not exist to track and adjust generation at the distribution level, a significant penetration of DG could threaten the integrity of the distribution system. EPRI is investigating DG's potential impact on the utility grid and has allocated research money to develop technology that will provide electronic control of generation at the distribution level.

for $5000–$6000 that provides enough power to meet your residential needs," he says. "And when you buy your house in the year 2000, instead of a furnace in the basement there could be a fuel cell." Noting that it is common for gas utilities to sell appliances and maintain service contracts, he suggests that such fuel cells could be provided by either a nonutility or a utility company. "Utilities could carve out a niche for themselves in this market, serving as both the supplier of the units and a servicer of them, while providing a backup power line to the customer in the event of problems with the unit."

A different tack

EPRI is working to help utilities like NSP find valuable niche applications for DG on their systems. As Dan Rastler of EPRI points out, existing utility planning methods are not appropriate for DG applications. "Conventional generation planning focuses on finding the least-cost bulk power generation option to meet a given demand," says Rastler, who is managing some of EPRI's DG studies. "This approach does not account for the full array of costs associated with the delivery of that power to the customers who will use it. Nor does it account for the option of utilizing advanced, modular generation resources."

Under Rastler's direction, EPRI researchers have developed a new, bottom-up planning approach to help utilities identify and evaluate high-value applications for DG on their systems. "This approach is a way of planning from the customer back to utility headquarters, instead of the other way around," says Rastler. "By starting with the perspective of specific customer needs, utilities can account for any related T&D expenses required to meet those needs, as well as any avoided costs, and find a least-cost plan that will also provide enhanced customer service." After all, he says, "It's not good enough anymore to be the lowest-cost generator. What really matters in this business is who can deliver the lowest-cost service."

The new approach is embodied in a planning framework that offers methodologies for quantifying the cost-effectiveness of DG technologies and their associated benefits. It was developed by working with member utilities on a series of in-depth case studies evaluating potential DG applications of high value. "Because tools currently do not exist for evaluating and optimizing a system that includes DG, we took a manageable, near-term approach to identifying where DG really has high value," says Mohamed El-Gasseir, the EPRI contractor who developed the bottom-up methodology. "The approach relies heavily on using an interdisciplinary team from the utility to identify DG applications within specific areas." The framework will be laid out in a guidelines publication, which EPRI expects to release by the end of the year.

A locally targeted approach was also used by PG&E and EPRI to analyze the potential benefits that DSM programs could offer in the utility's rapidly growing Delta District. Currently utility DSM programs are implemented systemwide, so the benefits are averaged over diverse geographic regions. By contrast, locally targeted DSM programs—which are expected to precede and supplement some DG applications—could be used to achieve not only energy savings but also some of the same benefits as modular generation units, such as deferred T&D upgrades and reduced emissions in specific regions. The Delta District study concluded that the integration of DSM with T&D planning to accommodate the growth in this region would be 30% less expensive than the alternative—the $112 million supply-side option of building a new distribution substation and upgrading T&D capacity.

Not only is planning from the customer back to the utility useful for identifying individual high-value applications for DG, it would be a necessary part of generation planning under the distributed utility concept, experts say. Operating a distributed utility would require a much higher degree of integration among generation, T&D, and marketing functions than exists under conventional utility organization.

According to Ren Orans of Energy and Environmental Economics, who was among the first industry analysts to point out the strategic advantages of viewing T&D expenses as a controllable cost of service, utilities will need full knowledge of their actual costs in serving customers in order to successfully exploit the cost-effective DG opportunities in their service territories. Currently utilities do not differentiate their costs according to location in their service territories but rather differentiate them according to customer classification—residential, commercial, or industrial. As Orans explains, this creates a problem in determining the best applications for DG. "For the really high value DG applications, the current costing system may be fine for now. But when it comes to identifying applications for distributed generation on a broader scale, the incentives for making cost-effective DG investments aren't always apparent." For instance, an area that is particularly costly to serve—and that is hence a good candidate for DG—may not be readily identifiable as such, since utilities average their system costs over the entire pool of customers.

One of the insights that has driven research on distributed generation is that utilities can get closer to the true cost of serving a specific area by differentiating costs not only according to location but

DISTRIBUTED GENERATION CAN BE COST-EFFECTIVE **Whether distributed generation is cost-effective depends largely on the site at which it is applied. This graph shows the results of a cost-effectiveness study EPRI researchers conducted for the use of a current-technology natural-gas-fired engine at an investor-owned utility site identified as offering high value for DG. The chart illustrates how the local benefits from DG (such as the deferral of T&D upgrades, reduced emissions, fuel diversity, and customer use of waste heat) can significantly reduce the higher initial cost of a DG technology. EPRI performed an analysis for the same site using fuel cell technology expected to be available in the year 2000 and found similar results.**

also according to time (as it pertains to the course of a utility's expansion plans). Traditionally, utilities have averaged the cost of equipment expenses over the lifetime of their expansion plans. But a utility's opportunities for avoided costs will vary over the years of their expansion plans. According to Orans, differentiating costs according to time would reflect such variations and therefore provide the information that utilities need in order to identify cost-effective DG applications.

Many economists working on the DG issue believe increased competition in the industry will prompt utilities to investigate their costing methodologies more closely. "Knowing regional costs will tell a utility where DG could be cost-effectively employed to help make its entire system more economically efficient," says Stephen Chapel, who oversees some of EPRI's economic research for storage and renewable energy technologies. Already PG&E, the Tennessee Valley Authority, Wisconsin Electric Power Company, and Central Maine Power Company have begun to explore the potential of differentiated costs.

But is it technically possible?

Even if utilities overcome the organizational and business hurdles to the widespread implementation of DG, the technical hurdles still raise some questions about the feasibility of the distributed utility concept. At this stage researchers do not know what technological effect widespread DG would have on utility systems. As Neal Balu, program manager for power system planning and operations at EPRI, points out, "If you sprinkle these DG units all over your distribution system, you have to make sure your distribution grid can take this kind of penetration. And we don't yet know whether the distribution system will be able to handle it. We don't know how the system will perform under these circumstances."

The concern is one of system security. Unlike other businesses, a utility has the obligation to ensure that at any instant in time—within fractions of a second—the total product being produced for its customers is equivalent to the total demand from the customers. This electrical balancing act is monitored by the system dispatcher, who helps ensure that the system operates at a stable 60 Hz. If the generation is greater than the load, the frequency of the system's power increases. If the generation falls short of the load, the frequency decreases. Both of these scenarios can cause a variety of power quality problems for customers throughout the system and can threaten the integrity of the entire system. To maintain the 60-Hz frequency, utility dispatchers rely on automatic generation controls—sophisticated computerized systems that electronically monitor demand and communicate with the generation units to adjust power production accordingly.

But these automatic generation control systems don't track generation at the distribution level. And according to Balu, the technology does not exist today to automatically record and adjust for such small power fluctuations. Balu says utilities have been able to accommodate the small amount of DG that already exists on their systems because the dispatcher receives the status of these units individually, by microwave or fiber-optic transmission. "But a massive implementation of these units is a different story," he says, pointing out that some DG units are nondispatchable, which means that they are not under the direct control of the utility dispatcher, so utilities have to accept the power whenever it is generated.

"If you've got 50 of these small, nondispatchable units connected to the same distribution line, there is a potential for overloading the line," Balu explains, noting that such conditions would require T&D upgrades. "All of this is obviously a function of the amount of DG penetration. If there's a 1% penetration in a relatively small area, there may not be much of a problem. If there's a 20% penetration in the same area, it will be a totally different situation." EPRI is studying the performance of the utility grid with respect to different penetrations of DG, using computer models to simulate how given networks will behave in terms of thermal loading, power flow, reliability, and other factors. In the meantime, the Institute has allocated research money to develop the technology that would provide the required level of control at the distribution level. The first generation of products to accomplish this task is expected to be commercially available in 1995.

Another technical concern is the issue of power quality. Poor power quality is being blamed for an increasing number of outages in U.S. businesses and homes. The advanced, electronic technologies that many companies are employing today are more sensitive than conventional technologies to disturbances that have always existed on the utility line. For instance, the switching of capacitors at a utility substation has caused adjustable-speed drives to trip, halting factory production lines. One U.S. automobile manufacturer reports that momentary outages resulting from poor power quality have cost as much as $300,000 per incident.

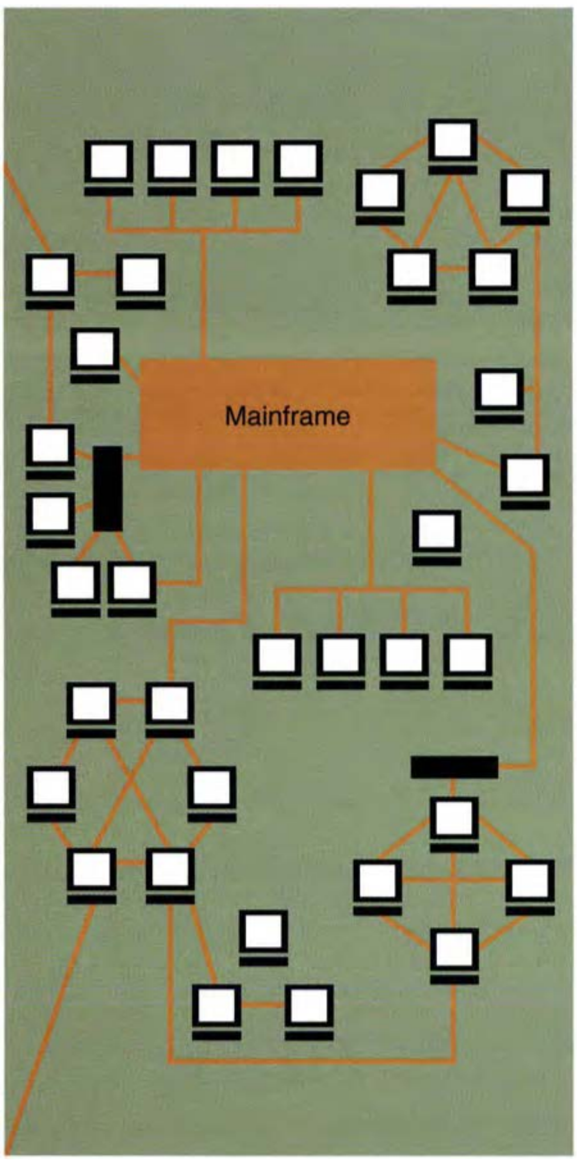
Some industry experts speculate that DG may improve power quality partly because the modular generation units would be placed close to the customer, alleviating disturbances associated with substation operations. Already, storage technologies connected to uninterruptible power supplies are being used to improve power quality in the commercial sector. Balu stresses that the potential power quality improvement benefit associated with other DG technologies is just a theory at this point. In fact, fuel cells and batteries generate harmonic disturbances not created by technologies with rotating equipment. "The question is, do these units generate disturbances that go back onto the utility line, causing new power quality problems? This is something we just don't know yet. We are still researching it."

The true potential

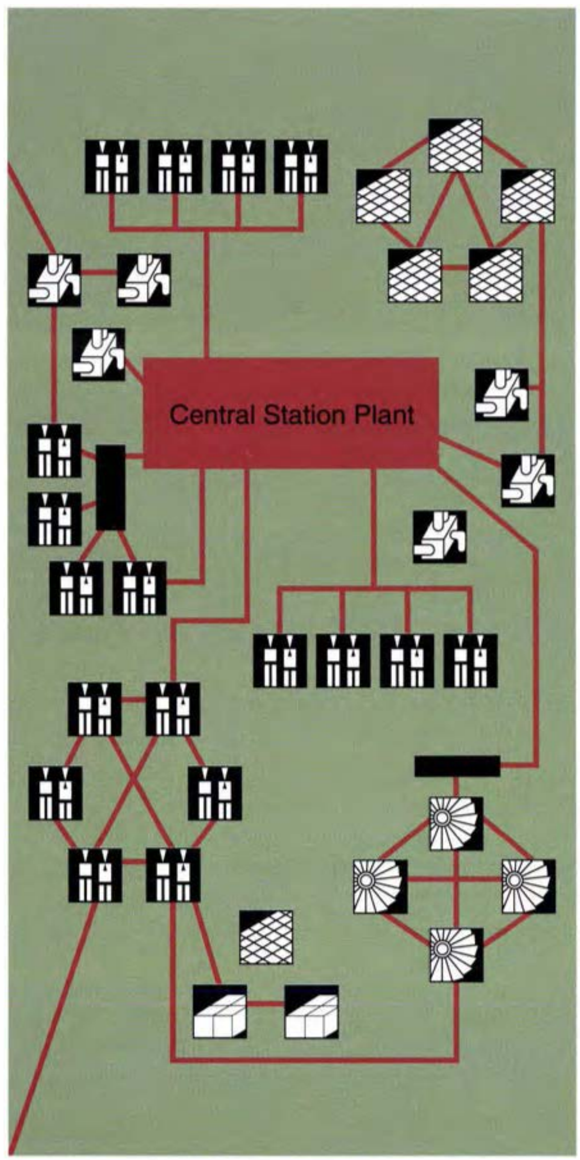
Accurately quantifying the local benefits of DG is critical to determining the potential of this technology for utilities;

Much as computer networks have evolved from mainframe-dominated systems to encompass a profusion of dispersed computing power in the form of personal computers, some industry analysts believe that vertically integrated utilities, which revolve around central station power plants, could evolve into distributed utilities. A distributed utility system would encompass numerous modular generation units located at or near customer facilities to supplement central station power and offer increased flexibility and other benefits not provided by large plants.

Computer networks of today



Utilities of tomorrow?



since DG units generally cost more per kilowatt than central station generation, the local benefits—which are not offered by central station plants—are a significant part of the value of DG and in some cases could offset the higher cost of these units.

EPRI has developed methodologies for estimating a value range for specific DG benefits under study at member utilities. So far, results for the high-value applications have been largely positive. In fact, they indicate that the value of local generation placed at specific sites within utility distribution systems may be up to two times the value of the generation if placed at the central station level.

However, as Rastler stresses, the studies conducted so far have investigated only the applications that utilities identified as having the highest value. These include the use of carbonate fuel cells for reduced emissions in some environmentally constrained areas within the Los Angeles Department of Water & Power's service area; the application of fuel cells within territories of Central and South West Corporation to defer T&D upgrades and enhance fuel diversity; and the implementation of diesel generators and fuel cells to defer a number of T&D upgrades and improve reliability of service within Oglethorpe Power Corporation's service territory. "We're being cautiously optimistic about the results," says Rastler. "We may have found that DG is economically feasible for these high-value applications. But this is just the first step toward finding the true potential for more widespread use. Whether DG could be implemented cost-effectively on a broader scale is still to be determined. I don't want to make DG sound like a panacea, because I don't think we understand all of the implications at this stage." (Additional EPRI studies are under way at the municipal Palo Alto Electric Utility, which is exploring the application of small diesel generators, gas-fired internal combustion engines, and phosphoric acid fuel cells, and at Salt River Project, which is investigating the implementation of photovoltaics.)

EPRI is getting to the heart of the fundamental questions about the feasibility of the distributed utility concept through its Distributed Utility Valuation Project. Rather than focusing only on potential high-value applications of DG technology, the project explores the widespread use of DG technologies throughout a utility system to optimize overall operations. "The distributed utility idea is tied up in some very important strategic business issues," says Jeremy Bloom of EPRI. "It may represent a fundamental change in the economics of the power business, so we'd like to get a sense of how it will affect the industry overall."

A joint effort of EPRI, DOE's National Renewable Energy Laboratory and its Pacific Northwest Laboratory, and PG&E, this study has resulted in a preliminary report, which is expected to be finalized for release early this summer. The report (TR-102461) explores the technical and economic feasibility of the distributed utility concept and highlights a number of issues that must be resolved before the concept can be properly evaluated. Among them are understanding the long-term trends in performance and cost characteristics of distributed utility technologies; developing planning methods that can incorporate not only bulk power generation resources and transmission systems but also distributed resources and distribution systems; determining and incorporating variations in area- and time-specific marginal costs; quantifying the value, if any, of the flexibility resulting from the modular nature of distributed resource technologies; specifying interfaces between distributed devices and existing transmission and distribution systems; and developing appropriate technologies and design criteria for operational control systems for handling large numbers of distributed units.

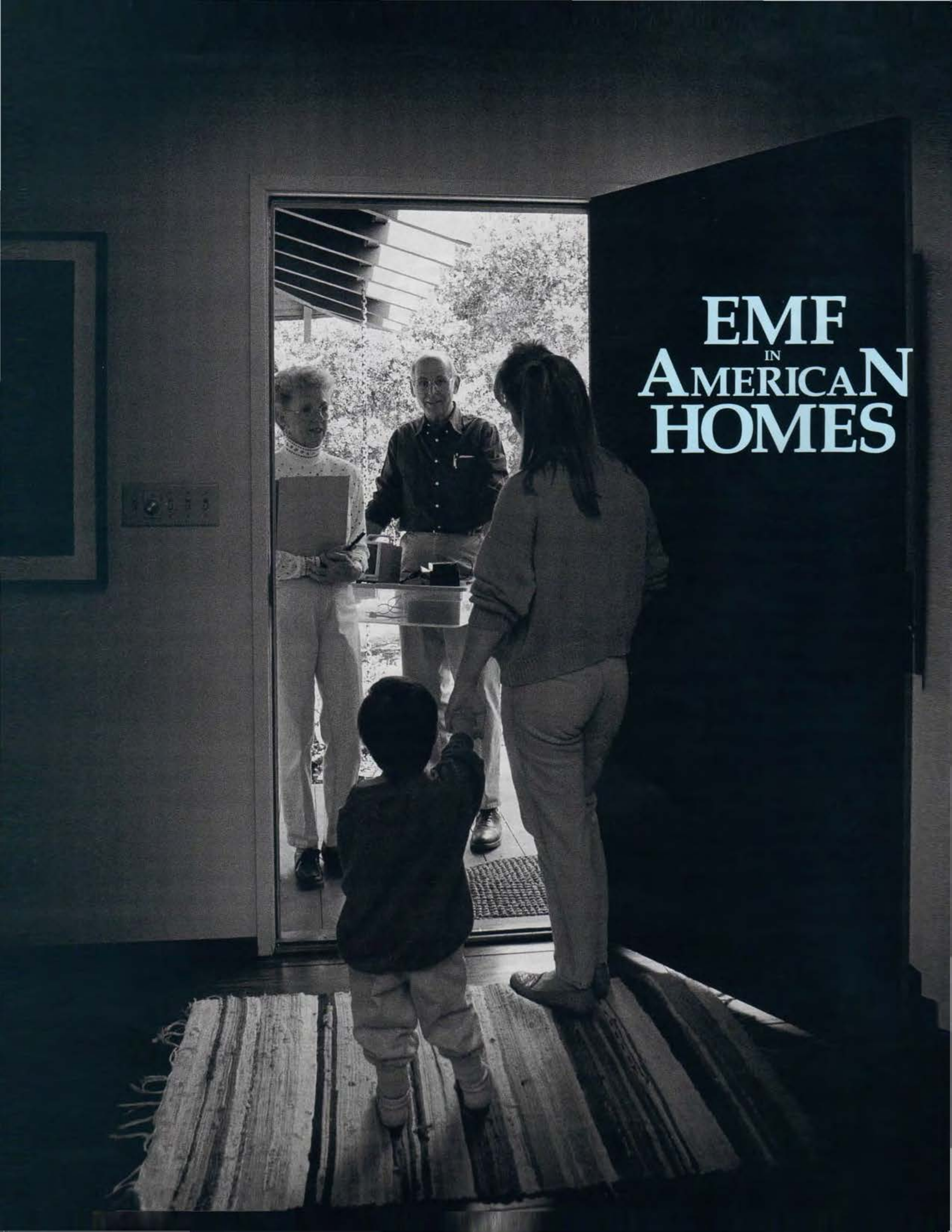
The report lays out a research agenda for tackling these issues and identifies some specific methodological approaches for EPRI to pursue. One of these approaches is an enhanced version of the model that PG&E and EPRI developed for the Delta District study to estimate the cost-effectiveness of targeting DSM programs in small planning areas. The enhanced version of this model also makes it possible to evaluate modular generation and storage technologies. The goal of the Distributed Utility Valuation Project for the end of the year is to have strong evidence indicating whether the distributed utility concept is economically attractive and whether it is technically feasible. The project will also assess the potential impacts on utility planning and operations.

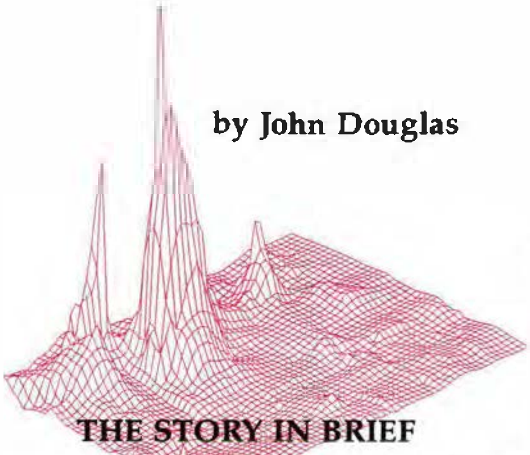
Some utility researchers, like Joe Iannucci, are optimistic about DG's potential. He believes DG technologies will represent a 10–30% penetration of the industry's new generation by 2010. "Many utilities are open-minded about the distributed utility concept," he says. "The alternative is to plan your utility in two halves—one that plans T&D and one that focuses on the central station. We cannot continue to optimize these two halves separately if we're interested in lowering the cost of service."

Researchers concur that DG will undoubtedly prove valuable for utilities in certain site-specific applications. But whether the systemwide distributed utility concept will actually prove viable depends on a number of factors, including technological advances, the economics of production and delivery in emerging power systems, competition in the marketplace, the strength of the environmental movement, and the regulatory reception for the concept and the new planning methods that would accompany it. As Chapel observes, "The distributed utility is a new paradigm for the electric power industry. Even though the concept may look promising at this stage, our research could ultimately tell us that it is not feasible. And that's OK, because the insights we're gaining through our work are helping our members master the complex issues that are defining the future of the electric utility industry." ■

Background information for this article was provided by Dan Rastler and Stephen Chapel, Generation & Storage Division, and Jeremy Bloom, Integrated Energy Systems Division.

EMF IN AMERICAN HOMES





by John Douglas

THE STORY IN BRIEF

Although public concern about exposure to electric and magnetic fields (EMF) has risen because of recent epidemiologic studies, little is known about the major EMF sources and average field levels in homes. To provide such information, EPRI has conducted a nationwide EMF survey of 1000 residences, designed to identify all significant sources of 60-Hz magnetic fields and estimate the percentage of homes where average fields exceed various levels. Preliminary analysis indicates that the most common residential EMF sources are appliances, ground currents, and power lines. Results of the survey can help guide utilities in responding to customer queries, provide valuable information for ongoing health studies, and suggest directions for field management research.

As interest in the possible health effects of exposure to electric and magnetic fields (EMF) increases, the question of which EMF sources are most significant gains importance. Although epidemiologic studies have indicated possible connections between exposure to magnetic fields and certain forms of cancer, little is known about which exposure characteristics may be most important—brief encounters with intense fields, for example, or chronic exposure to low-level fields. As public concern rises, more information is needed on residential field characteristics and levels and on the major sources of EMF in homes.

To help address these issues, EPRI has conducted a nationwide survey of 1000 residences randomly selected within the service areas of 25 member utilities. Specifically, the survey was designed to identify all significant sources of 60-Hz magnetic fields in residences and to estimate the percentage of residences where average fields exceed certain levels. Also explored was the relationship between sources and fields, as well as the way fields vary with location and time. Fields from appliances, for example, tend to be high close to the appliance when it is operating; those from power lines and grounding systems are lower but more pervasive in a residence. Such information about field sources will be critical for efforts to predict and manage fields under various circumstances.

Data gathered in the survey will also be used by health effects researchers to help resolve some remaining uncertainties in epidemiologic studies. Specifically, a careful analysis of residential fields and nearby power line configurations may help shed light on the significance of so-called wire codes, qualitative descriptions of power lines used to estimate past EMF exposure in several epidemiologic studies. The survey was not intended, however, to measure personal exposure to fields, since that depends on people's activities—how long they spend in each room, for example, or how close they stand to certain appliances.

"This study has produced a large database showing what magnetic field sources and levels are in real homes," says Karl Stahlkopf, director of EPRI's Electrical Systems Division. "The EMF issue still has a lot of unknowns. This survey has shown what levels of fields are commonly encountered in homes; now our job is to evaluate practical ways to reduce these levels, if warranted. The residential survey can serve as a valuable resource for future research, both in helping resolve uncertainties about health effects and in establishing priorities for field mitigation efforts."

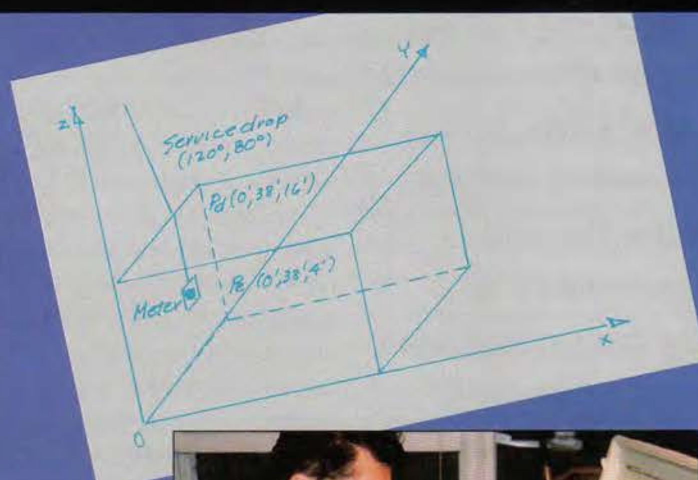
Making the measurements

Because of the magnitude and complexity of the 1000-home survey, a pilot study was initially conducted to develop techniques for magnetic field source identification and field level measurement. These techniques were then applied, during Phase 1 of the survey, to 162 residences to check the validity and practicality of the survey protocol. As a result of this work, a few minor modifications were made to the protocol, mostly to improve the efficiency and reliability of the measurements. The remaining homes were then surveyed during Phase 2, with data collection completed in 1992. The survey protocol was developed by the staff of EPRI's High-Voltage Transmission Research Center (HVTRC) in Lenox, Massachusetts.

The instrument used to measure fields in residences selected for the 1000-home survey was a stand-alone recorder called STAR, which was developed at HVTRC. Based on microprocessor technology, STAR is a highly portable device that samples and records fields along three axes at specified intervals. With a resolution of less than 0.1 milligauss (mG), the device is able to detect the low-level fields generally encountered in residences.

During the survey, STAR was used in two modes. In the first mode, which involved measuring the spatial distribution of fields, a STAR unit was mounted on a calibrated surveying instrument called a VANA wheel. The wheel was then rolled throughout the interior of a residence and around the yard in order to construct a

HOW MEASUREMENTS WERE MADE The 1000-home survey protocol included several types of measurements to produce a robust accounting of residential magnetic fields. To record the spatial distribution of fields, a stand-alone recorder called STAR was mounted on a calibrated VANA surveying instrument and guided along a grid pattern both inside and outside the residence. Sketches of the two environments were made to indicate the position of field sources, such as appliances, distribution lines, and service drops. Fields from operating appliances were measured separately, using three STAR instruments attached to a support at distances of 1, 2, and 4 feet. And four STARs were left in the residence for 24 hours to determine how fields changed over time. After all the measurements were made, data from the recorders were downloaded into a computer for documentation and analysis.



computerized profile of field strengths along the paths of travel. In the second mode of operation, STAR units were used without the wheel to record changes in fields over time in specific areas and to measure spot levels at different distances from appliances.

Measurements at each residence were taken by a two-person survey team, usually accompanied by a representative of the host utility. The first visit to each residence lasted about an hour. One team member worked mainly inside, sketching the living areas and using STAR to make a map of fields inside the home. The second team member worked mainly outside, sketching the outside perimeter of the building, indicating the position of power lines, photographing the residence and power lines, and mapping a profile of the fields from the lines. Measurements of fields near selected appliances were made by using three STAR instruments attached to a support, so that field strengths were recorded at distances of approximately 1 foot, 2 feet, and 4 feet from appliances. Four recorders were then left inside the residence for 24 hours. The next day, the survey team returned to collect the recorders and to make any repeat measurements for which a preliminary data analysis suggested a need. After these measurements were made, the STAR data were downloaded into a personal computer for analysis, which included the production of graphs showing field profiles inside and outside the home.

Survey teams were selected and trained by Enertech Consultants of Campbell, California. Most of the teams were retired couples, and one member of the couple usually had some technical background. Each team received one week of training at Enertech, which focused primarily on how to interact with residents. Then the teams went to HVTRC with an Enertech trainer to learn the measurement protocol. Finally, each team spent a week practicing in the homes of volunteers in Baltimore, again under the supervision of an Enertech trainer.

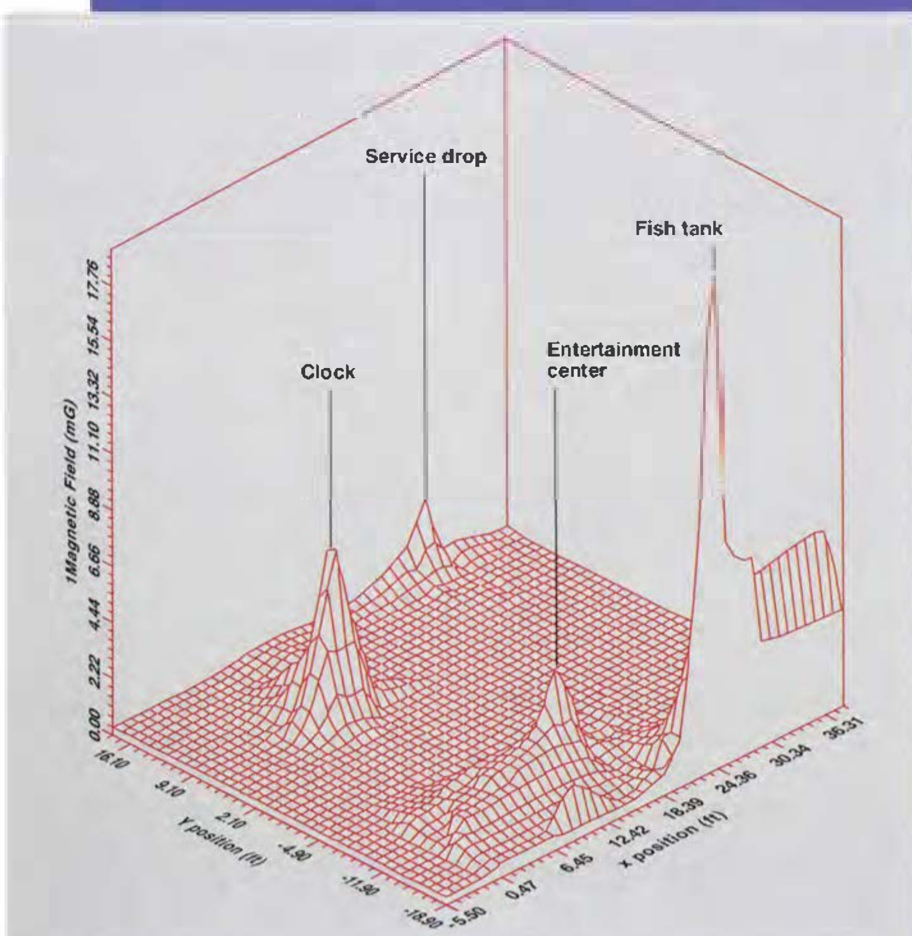
"We were particularly concerned to find teams that would stick together through the whole survey," says Michael Silva, president of Enertech. "We found that these teams were well accepted; retired couples don't look very intimidating. Taking a personal approach is the key to establishing the trust that is needed in a survey like this. Several people even made cookies for the teams, and the utility representatives generally had pleasant experiences. One even said that the survey 'set a new standard for good relations on a touchy subject.'"

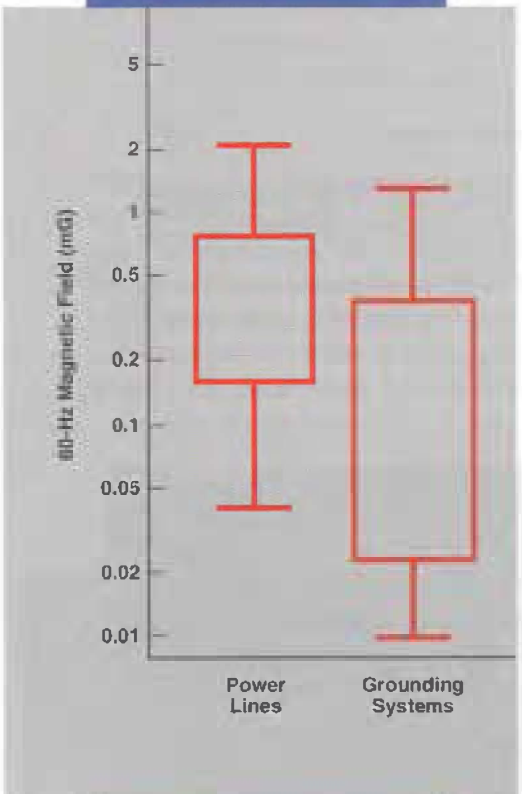
Given the large amounts of information collected for each residence, data management became a complicated task. Four software packages were developed specifically to characterize residential fields; the work was conducted at the computer facilities of HVTRC, which is responsible for data analysis related to the survey.

Initial results

An interim report based on measurements at the first 707 residences has recently been published (TR-100194), and a final report on the project is expected later this year. Preliminary analysis of data from the first 707 residences found that the most common sources of 60-Hz magnetic fields

RESIDENTIAL FIELD CONTOURS The STAR/VANA data can be used to produce a computer-generated contour map of magnetic fields in a residence. In the living room shown here, field levels were generally well under 0.5 mG. However, a clock, the utility service drop, an entertainment center, and a fish tank motor all produced peak fields, with the latter registering a surprising 20 mG.





MEDIAN FIELDS A key result of the nationwide survey was information about the distribution of median magnetic fields produced by power lines and by the grounding systems in homes. In each plot, half of the median values lie within the range indicated by the box, with another 20% lying in each of the two ranges indicated by the "whisker" lines. The top 5% and the bottom 5% of values lie above and below these lines. Generally, power lines are the dominant source of fields for a home considered as a whole, but in smaller areas, such as parts of a room, fields from ground currents are often larger.

were electrical appliances, the grounding systems for residences, and power lines. Normally, internal wiring was not a significant field source in homes. Results showing the importance of grounding systems were particularly interesting, since currents in water pipes and other grounding paths may be the major nonappliance field source in many homes. The field from ground current varies with electrical loads on the premises or even at neighbors' houses.

The median field value for all rooms in the residences—based on spot measurements taken without reference to specific sources—was 0.5 mG. Kitchens generally had higher median field strengths, 0.7 mG. About 10% of the homes had all-room median field values of 1.9 mG or more; 5% had values of 2.7 mG or more.

The highest peak fields were produced by appliances. Eight different appliance types were considered, and photographs were taken of each appliance to aid in further evaluation of subsets, if desired at some future time. At a distance of 10.5 inches from the appliance—the closest measurement point—a median field of 2.5 mG was found for 367 refrigerators surveyed, 8.5 mG for 272 electric ranges, 6.6 mG for 397 color television sets, 36.0 mG for 371 microwave ovens, and 14.3 mG for 97 analog clocks and clock radios. As expected, fields from appliances were found to fall off more rapidly with distance than fields from power lines and grounding systems; refrigerators, for example, produced median fields of 1.1 mG at 22 inches and 0.4 mG at 46 inches.

For the 24-hour measurements, the dominant field sources were power lines and grounding systems. Power lines were generally the most significant source of fields when the house was considered as a whole. In smaller areas, such as parts of a room, ground currents were often the predominant source.

In a few cases, special wiring arrangements produced significant fields. Old-fashioned knob-and-tube wiring, for example, was found in about 7% of the residences. Such wiring produces higher fields than modern wiring because the wires are spaced more widely apart than in today's cables, so fields do not self-cancel as effectively. Also, a few of the survey homes have radiant heating units in floors or ceilings, which use loops of wire that can contribute to higher field levels in the living spaces.

"The 1000-home survey has produced a definitive database on residential fields that will be mined for years to come," says EPRI research manager John Dunlap. "In particular, it provides a major planning tool for future research on field management, enabling us to concentrate on the most important sources. EPRI will spend more than $4 million in 1993 on evaluating ways to manage magnetic fields from the power delivery system, including grounding."

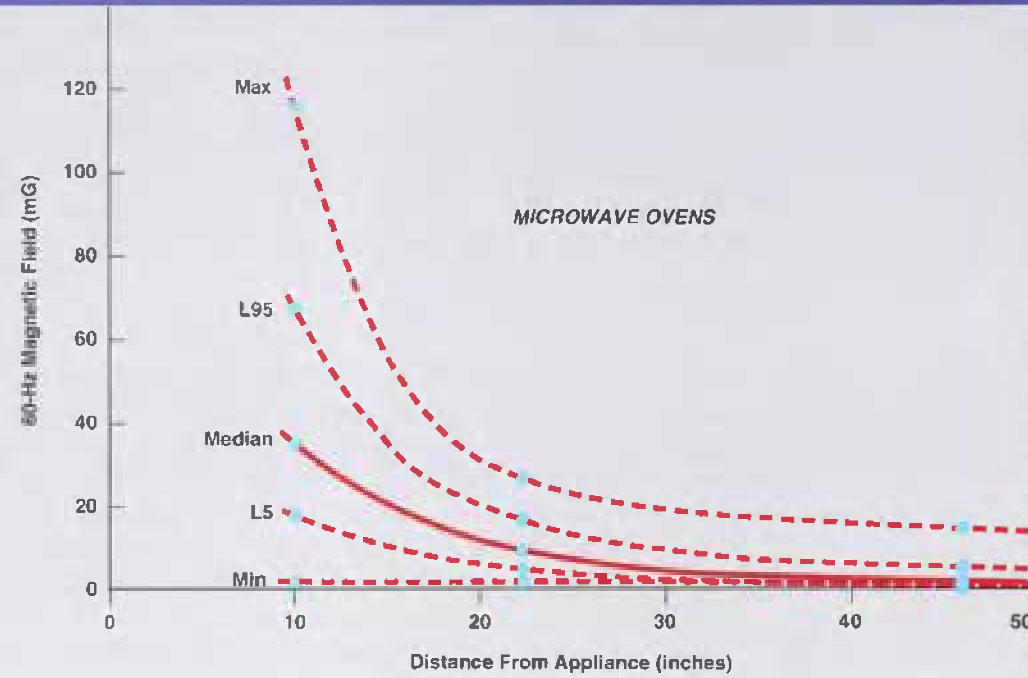
The question of grounding

Grounding one wire (the neutral wire) of an electrical distribution system is generally required because it provides an important safety feature for customers: if there is an electrical fault, grounding permits fast operation of a fuse or circuit breaker, which keeps people from getting shocked and prevents fires. Specific grounding practices may vary from place to place, however, and continue to evolve as new standards are adopted.

Current practice in the United States, as set by the National Electrical Code, usually involves grounding the neutral wire at the electrical service entrance to a residence by attaching it either to a water pipe or to a long rod driven into the soil. Additional grounding connections may also be made; for example, the shield of a television cable—already grounded at its own service box—might also be attached to a water pipe.

Such multiple connections mean that ground currents can flow on different paths, including water pipes, telephone cables, and cable TV lines. Whereas magnetic fields created by a pair of closely spaced wires (for example, house wiring) tend to cancel each other, those produced by currents on such conductors as water pipes are not canceled. Even a relatively small current flowing on a pipe can be the source of a significant magnetic field in a residence.

FIELDS FROM APPLIANCES
Magnetic fields produced by appliances—such as fields from microwave ovens, shown here—decrease rapidly with distance and vary widely among various models. About 90% of the microwave units in the study produced fields within the range indicated by the lines above and below the median line.



The survey found that in many residences a substantial fraction of the return current flows on water pipes rather than through the neutral wire leading directly to a distribution transformer. It is also not unusual for the ground current in one residence to flow through interconnected water pipes to another residence, creating magnetic fields there.

The survey provided data about the residential distribution of magnetic fields caused by ground currents. Residences with the highest grounding system fields (the top 5%) were categorized, for example, by residence type, age, and location and by the type of distribution lines serving the residence. Observations of actual sources of magnetic fields made during the survey will aid in determining what changes in grounding practice might reduce residential fields. Obviously, safety considerations related to shock and fire cannot be compromised.

In November 1992, EPRI held a workshop at Michigan State University to share information and develop plans related to magnetic field management research and the safety codes regulating residential grounding. This workshop was attended by utility representatives, safety code panelists, trade union representatives, regulators, and EPRI staff. Any code modifications related to grounding would require consensus among the many parties involved. Individual utilities—and especially customers—are not advised to take action on their own.

One example of how EPRI is helping provide technical information to code makers is work being funded with Empire State Electric Energy Research Corporation to study the mechanism by which ground currents create magnetic fields. This research also entails a review of grounding practices in other countries and their possible effects on magnetic fields. In some countries, for example, an additional wire is carried back to the distribution transformer, where a ground connection is made.

Fields from power lines

Another major thrust of the survey was to determine the relationships between residential magnetic fields and various power line characteristics. For this purpose, 24 types of power lines were identified, including underground distribution cable, various combinations of primary and secondary overhead distribution lines, and transmission lines. The largest median fields were produced by three line types: three-phase primary and secondary lines with separate neutrals, two three-phase primaries and a secondary with a common neutral on the same pole, and transmission lines.

Power line fields were also correlated to residential areas, with the highest median fields found in urban areas and the lowest in rural areas. Among types of residences, apartment buildings and duplexes had the highest median fields; single-family dwellings had the lowest. Median fields also tended to increase with the age of the residence: fields in homes less than 10 years old were about half those in homes more than 50 years old. The reasons for these variations are still being explored.

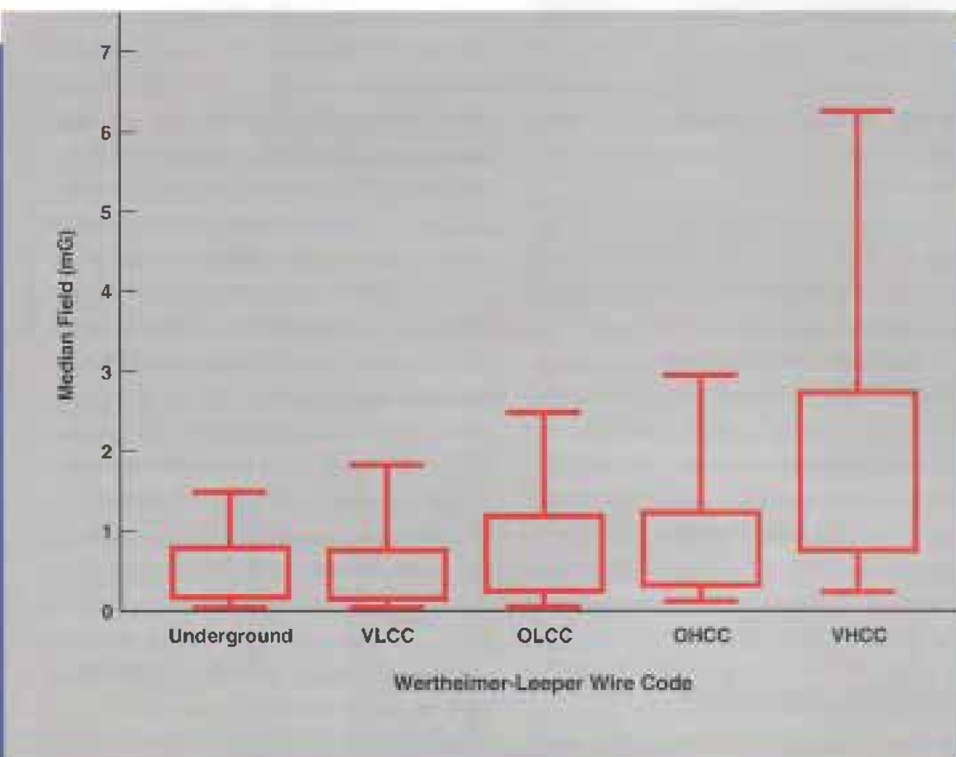
One problem faced by epidemiologists studying EMF exposure has been to find an appropriate way to codify types of overhead lines near homes to estimate what magnetic fields may have been present in the past. To help resolve this issue, residences in the 1000-home survey were assigned one of four wire codes according to a method developed by Nancy Wertheimer and Ed Leeper in early epidemiologic studies. (Underground distribution was considered as a separate category.) For example, a residence within 50 feet of a transmission line or three-phase distribution lines with thick primary wires was categorized as having a very high current configuration (VHCC). When the wire code assignments were compared with actual median power line fields and in-home spot measurements collected by the survey teams, the fields corresponding to the VHCC code were indeed substantially higher than those corresponding to the other wire code assignments. Measured fields corresponding to the three lower-current code assignments and underground lines were largely overlapping.

More analysis will be needed before researchers can understand why the associations between health effects and wire codes in epidemiologic studies have been consistently stronger than the associations between health effects and actual field measurements. Robert Kavet of EPRI's Environment Division is using data from the 1000-home survey to examine possible refinements in the procedure for assigning wire codes. "The Wertheimer-Leeper wire code classifies a home by the highest-ranking source outside," he explains. "We want to expand this classification system to include multiple lines, whose fields could all contribute. This work is now under way, and we expect to have initial results later this year."

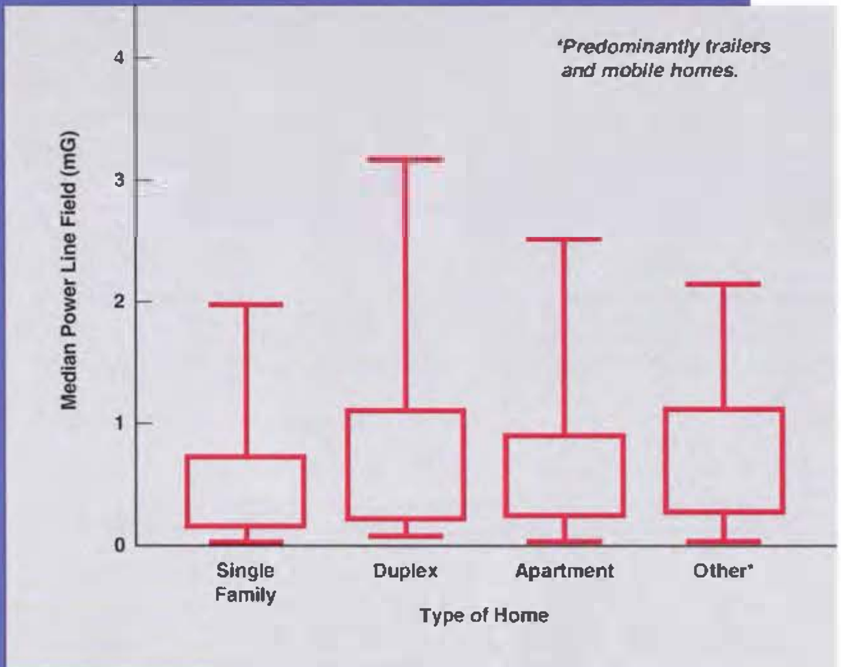
Harmonic field characterization

One of the key unknowns in EMF research is what characteristics of fields may be most important in possible health effects. For example, epidemiologists are interested to learn whether standard 60-Hz fields or higher-frequency harmonics may be associated with possible EMF health effects. Harmonic fields are often caused by appliances, especially those controlled by solid-state devices. In preparation for the nationwide survey, a more elaborate protocol was used at the homes of 18 utility employees. Although the main purpose of these additional measurements was to validate the protocol to be used in the larger survey, a detailed characterization of harmonic magnetic fields was also conducted.

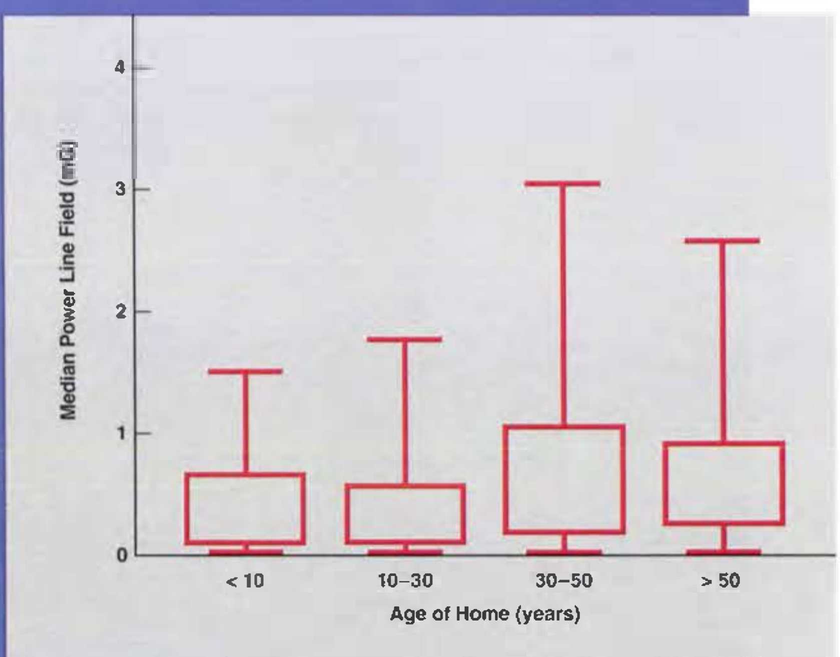
The more elaborate measurements were made with the MultiWave field monitoring system, which was developed for EPRI by Electric Research and Management. This system uses multiple sensors to measure magnetic fields simultaneously throughout a residence and relate them to currents in selected wires and ground circuits. MultiWave can also measure field orientation along three axes at each probe. Such orientation data can be used to determine the extent to which residential magnetic fields are polarized—that is, are stronger in some directions than in others. For the extended protocol at the utility employees' homes, MultiWave units with 8 to 16 magnetic field probes and up to 4



FIELD DISTRIBUTION BY WIRE CODE
One of the most important questions about the possible link between EMF exposure and health effects is the significance of so-called wire codes, used to estimate residential field strengths by visual inspection of nearby power lines. Spot measurements taken during the survey revealed that homes categorized as having a very high current configuration—or VHCC—do generally have higher fields than homes in the other wire code categories. However, values for homes in the lower categories overlap to the extent that the relationship between fields and wire codes is not statistically significant.



RESIDENTIAL VARIATIONS Median values of power line fields differed somewhat according to the type and age of the residence. Single-family houses, for example, had the lowest median fields, and newer homes tended to have lower fields than older homes. While these differences are interesting, researchers have not yet found clear explanations for them.



current probes were deployed at each site and recorded fields of various frequencies for 24 hours.

The harmonic analysis performed on data from the employees' homes showed that the difference between the ordinary 60-Hz field and the total magnetic field including all harmonics was generally less than 1% but could occasionally be as great as 15–20%. The average total harmonic field was 0.1 mG; 10% of harmonic fields were above 0.2 mG. The third harmonic (180 Hz) was by far the strongest component. Measurements with MultiWave also showed that fields in residences were slightly elliptically polarized. While the main goal of the survey was to quantify 60-Hz fields and sources, this information on harmonics and polarization may be valuable if health studies show these factors to have biological significance.

A critical time

Beyond its immediate importance for research in the United States, the 1000-home survey has also set a standard for similar work in other countries. One of EPRI's international affiliates, for example, is currently using information from this project to conduct a survey of its own system. EPRI provided the utility with measurement protocols, instruments, analysis software, sample brochures for the public, training at HVTRC for utility staff, and hotline support during the survey.

"The data from the 1000-home survey come at a critical time," concludes Karl Stahlkopf. "Public interest has been raised by attention to the issue in the popular media. People want to know what fields they're exposed to, and from which sources. The results of this survey can help guide individual utilities as they respond to customer queries on this subject. In addition, the results provide valuable information for ongoing health studies, quantify the role of ground currents in generating magnetic fields in homes, and help us plan research into various field management options."

Background information for this article was provided by John Dunlap and Karl Stahlkopf, Electrical Systems Division, and Robert Kavet, Environment Division.

Videoconferencing: Fac

by Judith

Now in its second year, EPRI's digital videoconferencing program saves time and mon complement of audiovisual aids. As more and more member utilities link up with the Insti communication, problem solving, a

Every Tuesday morning Rick Squires takes a three-minute walk from his office in Palo Alto, California, and spends an hour and a half with his colleagues at PowerGen, near Nottingham, England. He's back at his desk well before lunch. Squires, a loaned employee at EPRI, hasn't taken up astral travel—his transport medium is compressed digital videoconferencing, a technology that is increasingly preferred as a low-stress, low-cost option for long-distance utility business sessions.

To many in the industry, the value of videoconferencing seems obvious. David Parker of Central and South West Corporation is one of them: "When someone asks, 'Why hold a videoconference instead of an audio conference call?' I respond, 'Why do you leave your desk to go to a meeting rather than conducting all your business over the phone?' " Another enthusiast is Dave Cadwell of Tennessee Valley Authority. "The immediacy of talking face-to-face with someone at a distant location can hardly be overrated," he says. In fact, he adds, videoconferencing concentrates the experience: "Often I find myself even more focused in a videoconference than if I'm actually sitting across the table from someone."

Interactive, low-cost, and using equipment that's easy to plug in and operate, digital videoconferencing offers immediate, practical relief for EPRI's travel-worn staff while bolstering the Institute's ability to respond quickly to members' needs. Moreover, it seems tailor-made to support both the increasing deployment of EPRI staff to technology centers and regional offices across the country and EPRI's expanding global outreach.

At one-tenth the operating cost of one-way broadcast conferencing, the digital video technology delivers roughly the same visual image—and adds to it face-to-face give-and-take from two-way monitors in as many as 16 sites at one time. It also can include computer, recording, and film/document/slide-projection capabilities. The down side is a sometimes blurred picture and an annoying time lag in sound transmission. There are good reasons to expect those technical problems to fade, however. Improvements since the first-generation systems of the 1980s have already cut the sound delay from three seconds to half a second. And local telephone services are rapidly upgrading to the high-speed digital circuits required for this and other cutting-edge electronic technologies, which should soon ease the shortages that now limit installations in some localities.

The initiative

In May 1991 Dick Balzhiser, EPRI's president, and Ric Rudman, senior vice president for business operations, launched a corporate initiative to explore the potential of videoconferencing to add a vital

e to Face at a Distance

Quinn

ey by providing face-to-face interaction across thousands of miles, supported by a full tute for long-distance meetings, the system is fast becoming a mainstay tool for efficient nd value-added technology transfer.

new dimension to communications and technology transfer in the industry. "With the increasing time pressures on us all, we feel the time is right for this technology," said Balzhiser in a letter to member CEOs. "Knowledge is EPRI's business, and we are constantly searching for ways to disseminate it more effectively, using cost-reducing and time-saving techniques."

Recent technical advances had presented an irresistible opportunity, as Rudman explained at that time. "Equipment and transmission costs are down, reliable technology has arrived, and international standards to ensure connectivity among different systems are emerging." In round numbers, the initial EPRI investment per site in 1991 was just over half what it would have been two years earlier. Moreover, the coast-to-coast transmission cost had dropped to $30 an hour from the 1989 cost of $600 an hour. The total equipment cost—for two monitors; a video camera; a document camera that can display onscreen any page, 35-mm slide, or three-dimensional object laid on it; an integrated VCR; and a slide projector—was approximately $56,000 (lowered in 1993 to $53,000). In addition, the Palo Alto startup costs included $3000 for the installation of two 56-kilobit high-speed digital telephone lines, plus remodeling (many sites need little or no remodeling) and integrated Macintosh and IBM personal computers that supply onscreen access to EPRINET and other EPRI computer resources as needed. In comparison, to install a television-style broadcasting setup in 1991 would have required a startup investment of $1,000,000 and $1000–$1500 an hour for transmission in the United States.

Economy is not the only advantage of digital videoconferencing, however. Equally important in today's urgent business world may be its portability and its on-tap availability. In these terms, the difference between broadcasting and digital videoconferencing is essentially the difference between engineering a cross-country television hookup and making a long-distance phone call. Once the required high-speed phone circuits are installed, the digital equipment can be rolled to any jack on the circuit and plugged right in; the equipment uses a normal power outlet. A simple two-way conference can be arranged with a phone call. Sessions involving several sites or diverse equipment may take a day or so to set up, but never the weeks required to schedule air time for a broadcast conference and then to professionally transport and set up the equipment. So for small, interactive business sessions, videoconferencing is usually the way to go, although broadcasting—with its sharp, TV-quality picture and wireless satellite transmission—still holds the advantage for large gatherings, for mass access over wide geographic areas, and for some special events.

When the EPRI initiative began, several innovative utilities were already video veterans, having relied on the technology for communication with outlying plants and offices since the late 1980s. Florida Power & Light, for example, had had a system for executive use since 1988. And the New York Power Authority, in a distinctly local application, had a system to monitor ice buildup on the Niagara River. Other members, which had not invested in equipment of their own, had been using nearby government, university, or commercial facilities.

EPRI's idea was to capitalize on that base. By supporting the acquisition and use of videoconferencing equipment by members and industry associates, the Institute would make its staff more accessible and would open an effective new channel for delivering its R&D results. In addition, by establishing videoconferencing sites at convenient EPRI locations, it would offer low-risk opportunities for members and associates to try out and master a communications medium that will come increasingly into play. And, almost as a by-product, together they would lay the groundwork for a powerful communications network for the industry.

Formally, the initiative offered members, international affiliates, and industry associates special price discounts on equipment from a leading vendor, along with consulting support from EPRI's information technology professionals on purchase decisions and installation. In addition, the Institute made the videoconferencing facilities at EPRI centers available to these organizations at cost for use on EPRI-related business. It also extended staff assistance for scheduling videoconferences at EPRI-related facilities and for referrals to compatible commercial facilities in 68 U.S. cities and in 35 nations around the world.

The Institute selected its equipment after conducting comprehensive tests of leading product lines in April 1991 and carefully considering price, quality, operating costs, and compliance with emerging international standards. Vendor commitment to the development of desktop videoconferencing counted as well. The overall goals were cost-effectiveness and protection against premature obsolescence as the technology matures.

By November 1991, EPRI video centers were operating in Palo Alto, in Washington, D.C., and at the Nondestructive Evaluation Center in Charlotte, North Carolina. A year later, EPRI had nine active facilities across the United States and another at its European office in Birmingham, England. By the end of 1992, some 15 members, affiliates, and industry associates had purchased 68 systems and 5 bridges (for multisite conferences and connections linking diverse equipment) through EPRI discounts. Others had decided on competing, though compatible, brands. In the course of the year, EPRI's information technology staff had consulted with more than 20 members on purchases and installations.

Beyond that, Bonneville Power Administration (with its link to the FTS-2000 federal video network) and San Diego Gas & Electric had joined with EPRI in pilot programs to test the potential of this medium for EPRI technology transfer.

In reporting to EPRI's Research Advisory Committee in March 1993, Ric Rudman told the group, "Our experience with EPRI's videoconferencing initiative over the past 16 months reinforces our interest in this technology. Current usage appears to justify EPRI's investment through savings in travel costs and staff time and improvements in business effectiveness. Beyond that, with the high level of interest displayed by member utilities thus far, we anticipate a growing network of facilities and increasing use of videoconferencing

A SUPERFLEXIBLE TOOL In addition to enabling live, face-to-face communication between participants at multiple sites, digital videoconferencing can accommodate a wide variety of integrated information media, including videotapes, slides, computer displays, graphic art, and even extreme close-ups of three-dimensional objects.

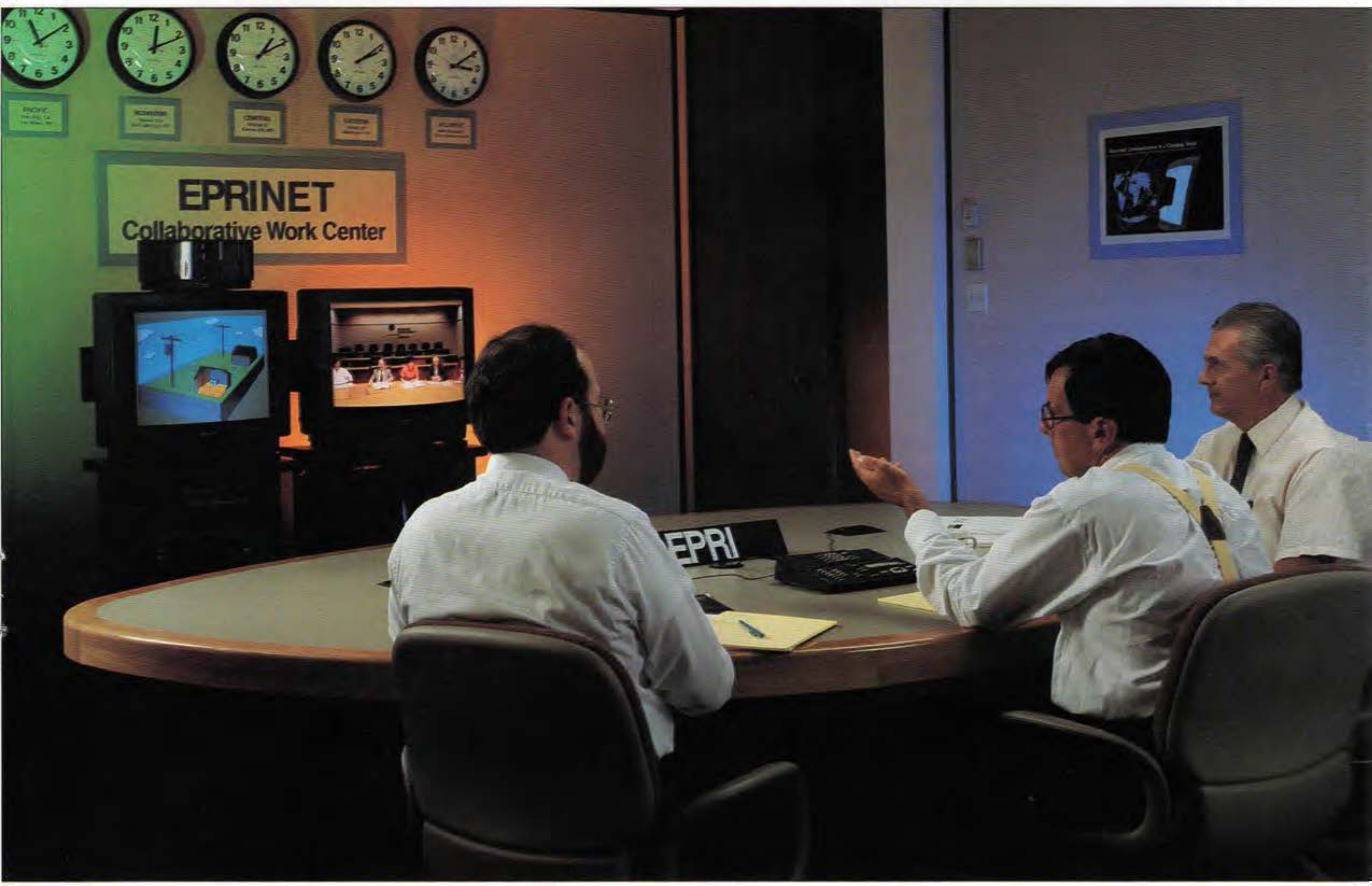
as an information and technology delivery medium."

At EPRI headquarters, with one full-scale video center and a mobile unit, usage grew in 1992 to an average of 30 conferences per month, not counting technical tests and demonstrations. Typically, these sessions involved 8 participants at 2 or more sites and lasted an hour and a half. Together, they included participants at 32 sites at 19 utilities, 11 sites belonging to 5 private contractors, and 2 sites at universities in the United States. They also included representatives of federal organizations, such as the Department of Energy, the Nuclear Regulatory Commission, and the Office of Management and Budget, and representatives of industry organizations, such as the National Association of Regulatory Utility Commissioners and the Nuclear Management and Resources Council. EPRI also held international videoconferences in Palo Alto with utility groups in Australia, Canada, Finland, France, Italy, the Netherlands, and the United Kingdom. At EPRI's Washington, D.C., office, an additional 2260 people—representatives of utilities, industry groups, and contractors, along with EPRI staff—participated in more than 200 videoconferences last year, mostly technical sessions with Palo Alto.

Back to you, Rick

To get a feel for the medium and its special qualities, let's return to Rick Squires and his Tuesday meetings. In March 1992 PowerGen, the privatized British utility that became EPRI's first international affiliate, sent Squires to Palo Alto on a two-year loan to EPRI's Environmental Control Systems Department. He's determined to make the most of the opportunity. "Our access to EPRI results gives PowerGen an important strategic edge in a highly competitive environment," he asserts. And he's calling on all available media to keep the connections humming here and across the Atlantic—using fax, e-mail (Squires logs some 20 hours a month on EPRINET), and videoconferences in support of his bedrock contacts at seminars and workshops. The videoconferences Squires has held weekly since September 29 are central. A fixture in EPRI's prime-time (morning) video schedule, they vary widely in cast and content, as Squires assembles a changing mix of EPRI and PowerGen staff for planning, consulting, and tech transfer.

Last December 15, for example, four



What About the Bottom Line?

In our interviews, participants named savings in travel costs as a prime attraction of videoconferencing. On the other hand, they also named startup and operating costs as a prime deterrent. The problem is that although the benefits seem undeniable, they are hard to quantify. You can't always capture the cost of an opportunity you missed because you didn't have time to make a trip, or the cost of unproductive time spent in an airport waiting for the next flight out. In many cases, however, you can quantify travel expenses and staff time saved.

In those terms, Greg Lamb, manager of electronic technology transfer for the Institute's Generation & Storage Division, calculated a fast payback on the $50,000 it cost to lease videoconferencing equipment the division placed temporarily with a Chicago contractor to enable close collaboration on a major project. "In even less than a year, we'd paid for the lease in travel savings," he says. "And with the weekly videoconferences, we've kept the project right on schedule."

Here's a generic comparison between an overnight coast-to-coast trip and a videoconference. Rule-of-thumb costs for a two-day overnight trip would be $1000 for air and ground transportation plus $200 for hotel and food, for a total of $1200, not counting the cost of unproductive staff time in transit. In contrast, the costs for a two-site, two-hour (longer than average) videoconference in the United States would be $125 an hour at the initiating site and $95 an hour at the receiving site (EPRI's cost-recovery-based rates, excluding depreciation), for a total cost of $440 if EPRI paid the charges at both ends. That's $1200 to send one staff member to the East Coast, compared with $440 to hold a two-hour videoconference.

This formula can be used to get an idea of savings Institute-wide. Assuming that each of the 360 videoconferences held in Palo Alto in 1992 replaced just one overnight trip to the East Coast for only one EPRI project manager, the Institute would have saved $273,600 in its travel budget last year. That is, the total savings in travel costs would have been $432,000 and the offsetting videoconferencing charges $158,400. □

COSTS: COAST-TO-COAST TRAVEL VERSUS VIDEOCONFERENCING

	Off-site Meeting	Videoconferencing
Costs		
Travel (air and ground)	$1000	—
Hotel and meals (one night)	$200	—
Telecommunications	—	$440*
Total costs	$1200†	$440
Time Expended		
Travel outbound	6 hours	—
Meeting	4 hours	2 hours
Meeting preparation	1 hour	2 hours
Travel home	6 hours	—
Total time expended	17 hours	4 hours

*For a 2-hour session between two sites, assuming EPRI's cost-recovery-based rates—$125 an hour at the initiating site and $95 an hour at the receiving site.

†Does not include the cost of one day of staff time spent in travel.

representatives of two EPRI programs met with three PowerGen staffers on a proposal to integrate an additional set of tests with a tailored collaboration project already under way for Southern Company Services. The added tests would use identical criteria in a brand-new, state-of-the-art test rig to determine the effects of coal quality on nitrogen oxide emissions from eight coals. "It's a win-win proposition," says Squires. "By joining forces, we'll all get twice the database with much more analytical potential."

The videoconference was a follow-up to explore EPRI's interest in the proposal and, if it was a go, to organize the next step—a more technical meeting in Birmingham, Alabama, with the project team from Southern Company Services. In an hour and a half, the group had clarified several technical and legal points, roughed out a letter of intent, reviewed paperwork requirements, and set the agenda, dates, and list of participants for Birmingham. The decks were cleared for a productive technical session. On the side, two participants in the videoconference arranged to tack an extra day onto the Birmingham meeting for work on another project.

Although the session was informal—jackets off, coffee cups in hand—the pace and tone were tightly focused. Such brevity and intensity are characteristic of videoconferences, possibly because of the tonic effect of being "on the meter" and having a time limit. (On the morning of December 15, Squires's session was only the first of three videoconferences scheduled back-to-back in the EPRI center.)

Some even say that the sound delay helps sharpen the focus. As Tom Rodenbaugh, EPRI's manager for underground transmission cable operations and software, sees it, "In a videoconference, people try to be clearer and they interrupt less, because of the voice delay." He adds, "We accomplish in three hours what would take a day to do on-site because everyone stays focused on business. We come out with action ideas. People are more attentive. There are fewer distractions, and we're aware that the time has to count." And, whatever the cause, Rick Squires has observed another benefit: "The people you want generally do show up for a videoconference."

Surveying success

By October 1992—somewhat over a year into the initiative—it was time to benchmark the experience of the utility staff, research contractors, and EPRI staff who had brought the Institute's videoconferencing initiative to life. In a quick, snapshot survey, telephone interviews with a small but representative sample yielded some interesting information.

How were these innovators using the medium? For briefings, for negotiations, for tech transfer, for job interviews, for project reviews, for staff meetings, and for technical demonstrations. Several training programs were in the works in 1993 for EPRINET and at EPRI technology centers, including the Monitoring & Diagnostic Center near Philadelphia. (*Distance learning* is the vogue term for the mix of tapes, live instruction, and long-distance interaction being developed for videoconference courses.)

What did users see as the benefits of videoconferencing? Both utility and EPRI staff ranked time savings as the most important benefit. They ranked cost-effectiveness second. And they ranked third the participation of people who don't usually travel to out-of-town meetings. A few of those interviewed also mentioned enhanced productivity and better communication.

What were the barriers to videoconferencing? The greatest deterrents were the costs (either the startup or the operating costs) and the sparse network of contacts. The technical barriers included the unavailability of high-speed phone lines in some localities and the sound delay and picture blurring.

Overall, the message from the survey was positive. Digital videoconferencing may be rough around the edges, but, as the following examples indicate, Rick Squires is only one of many in the industry who are netting solid payoffs from it every day.

This vivid medium has played a critical part more than once in making a business case. Bob Goodrich of Northeast Utilities recalls one early example: "We first used videoconferencing when one of our senior vice presidents took on the responsibility for R&D. He wanted to come up to speed quickly on EPRI and our relationship with it. EPRI arranged for several hourlong videoconferences, which provided the needed interaction with our EPRI counterparts at a fraction of the cost of travel."

With the video option at hand, both utility and EPRI staffs have found new power to make end runs around roadblocks and to pick up on sudden opportunities. One day last year, for example, Bob Leonard, director of communications at the New York Power Authority, made one of those end runs. He also saw firsthand just how novice-friendly the video equipment can be. "Shortly after we had installed our system and before we were able to train anybody on the equipment," he says, "about 10 of us from White Plains were supposed to fly and then drive to a presentation by a nuclear expert in Oswego, New York. Unfortunately, because of fog, the charter flight was canceled. When the expert arrived to give his three-hour talk, an important part of his audience was missing. In about an hour, we were able to set up a videoconference, using people who had never seen the equipment before. The presentation went very well and was conclusive evidence of the benefits and value of digital videoconferencing."

Tom Rodenbaugh, like other EPRI staff, welcomes the help with his tight schedule: "Our travel budget has been greatly reduced, so we have to plan further in advance and maximize each trip by going to multiple sites. That makes it very difficult to respond to a request for immediate travel. With videoconferencing, we can talk to utilities right away without having to take that trip." Ron Lambert of the Power Electronics Applications Center in Knoxville, Tennessee, also sees videoconferencing as a schedule-stretcher. "We're a small staff of 16," he says. "Traveling for a short meeting may take a three-day bite out of an engineer's week. With videoconferencing, we can look the other guy in the eye and still get back to our other business the same day."

Long-distance staff meetings are ap-

Questions? *Where to Call*

- For general questions, for a list of local EPRI and commercial facilities, or for a demonstration, call the EPRI videoconferencing coordinator at (415) 855-2886.
- To reserve time at an EPRI center, call the contact at least 48 hours in advance (72 hours for multiparty sessions or commercial sites).
- For information on equipment discounts and accelerated delivery dates, call your EPRI regional manager.

Want to Conference? *Use an EPRI Center Near You*

- Palo Alto, California: Sarah Brown, (415) 855-2886
- Washington, D.C.: Barbara Schrack, (202) 872-9222
- Birmingham, England: Sue Webb, 44-21-782-3007
- Combustion Turbine Center, Charlotte, North Carolina: Dell Mitchell, (704) 547-6121
- Customer Assistance Center, Dallas, Texas: Eileen Mattox, (214) 869-9773
- High-Sulfur Test Center, Barker, New York: Tom King, (716) 795-3397
- Monitoring & Diagnostic Center, Eddystone, Pennsylvania: John Niemkiewicz, (215) 595-8871, or Jeanne Harris, (215) 595-8875
- Nondestructive Evaluation Center, Charlotte, North Carolina: Dell Mitchell, (704) 547-6121
- Power Electronics Applications Center, Knoxville, Tennessee: Ron Lambert, (615) 974-8288
- Power Plant Computer Applications Demonstration Center, Chicago, Illinois: Mark Hepler, (312) 269-6766
- Thermal Storage Applications Center and Commercial Building Air Conditioning Center, Madison, Wisconsin: Bob Schultz, (608) 262-8221

Note: Members and industry associates may use the videoconferencing facilities at cost for EPRI-related activities. Also, compatible commercial facilities can be used for conferences with EPRI centers.

Is Your System Compatible? *How to Find Out*

Just call the EPRI coordinator at (415) 855-2886 with the following information:

- Name and telephone number of your videoconferencing coordinator.
- Brand of your videoconferencing equipment.
- Vendor and type of your high-speed phone circuits. If your vendor is not AT&T, are you registered with a U.S. Sprint or AT&T bridge?

Also Available on Video

Baltimore Gas & Electric Co.
Bonneville Power Administration
Carolina Power & Light Co.
Central and South West Corp.
Commonwealth Edison Co.
Consolidated Edison Co. of New York, Inc.
Duke Power Co.
Florida Power & Light Co.
Iowa Electric Light & Power Co.
Los Angeles Department of Water & Power
New York Power Authority
New York State Electric & Gas Corp.
Niagara Mohawk Power Corp.

Northeast Utilities
Public Service Co. of Oklahoma
San Diego Gas & Electric Co.
Southern Company
- Alabama Power Co.
- Georgia Power Co.
- Gulf Power Co.
- Mississippi Power Co.
- Savannah Electric and Power Co.
- Southern Company Services, Inc.
- Southern Nuclear Operating Co.

Tampa Electric Co.
Tennessee Valley Authority

INTERNATIONAL
AEM, Italy
Imatran Voima Oy, Finland
Nuclear Electric, United Kingdom
PowerGen, United Kingdom
Scottish Nuclear, United Kingdom
State Electricity Commission of Victoria, Australia

pearing on the video logbooks with increasing frequency. At Northeast Utilities, for example, the head of the nuclear group meets every morning with the superintendents of all the nuclear plants. As soon as Northeast acquired the Seabrook plant, its supervisor joined right in via videoconference from New Hampshire. "Videoconferencing is in its infancy at Northeast Utilities," says Bill Hosking, the supervisor of audio-video services. "We're still in an experimental phase, but I feel this technology has a lot of pluses. Our service territory covers New Hampshire and Massachusetts as well as Connecticut. Under these conditions, you need a rapid way of dealing with people. Digital video is an extension of the telephone that provides you with face-to-face capabilities."

Video bolsters EPRI's connection with its far-flung staff as well. In September 1991, the Institute's Nuclear Power Division relocated some employees to the Nondestructive Evaluation Center in Charlotte. "Videoconferencing has been an effective tool for maintaining good communication between the groups," says Norris Hirota, EPRI's manager for operations and maintenance cost reduction. "We accomplish almost the same level of work in our videoconference staff meetings as when we were all in Palo Alto."

Over time, other uses have also caught on at EPRI—negotiations, for example. According to Tom Guldman, senior licensing administrator, "Intellectual property negotiations typically take a lot of dialogue and exchange of offers. When you travel to a site, you often feel pressure to get closure, even when it might be better to let everyone reflect some more. We have been able to hold videoconferences in an atmosphere without any pressure to arrive at premature closure. Yet in all cases we actually have reached closure." Tom Rodenbaugh makes another point: "For a tough negotiating session, you don't have to leave your backup team behind. You can call on any one of them whenever their expertise comes into play—without taking a day out of their work schedule."

That access to more and better information is valued in other sessions too, as Jeff Burleson of Southern Company Services reports. "When our End-Use Technology Research Advisory Committee met via videoconference with program managers in EPRI's Customer Systems Division," he says, "we got a lot of good input and information we wouldn't have gotten otherwise. We wouldn't have been able to afford for all of us to fly to Palo Alto, and they couldn't all have come here." In short, you can have your whole dream team at a videoconference—including the specialists and the coaches—but you can usually afford to send only the captain to a distant meeting.

The future

In a ceremonial videoconference to launch the Bonneville Power Administration–EPRI pilot project, BPA Administrator Randall Hardy looked clearly beyond the bottom line to that bonus in value. "The challenge," he said, "is to make full use of this capability, not just for the travel economies but—more important—for gains in productivity, understanding, and communication."

At the same event, EPRI's vice president for information technology, Marina Mann, spoke of videoconferencing as a vital part of the Institute's electronic communications strategy: "This linkup is just a beginning. In a fast-changing world, the successful organizations will be those that have the information they need in time to act on it. EPRI is committed to delivering to its members electronic information media like videoconferencing that can provide that necessary information with the speed and mobility they require." With Mann as its representative on the Information Infrastructure Advisory Committee of the Council on Competitiveness (a private-sector nonprofit business coalition), EPRI is actively participating in efforts to develop advanced electronic information networks—an information superhighway—to serve the education, research, and business communities of the nation in the twenty-first century.

In the meantime, the demand for videoconferencing continues to build in the EPRI community. In January, for example, some 45 videoconferences took place in Palo Alto—a significant jump from the 30-per-month average at the end of last year and an indication that videoconferencing could well be the next technology to take the fast track to mass acceptance, like the photocopier, the fax, and the portable phone. ■

Background information for this article was provided by Marina Mann, Ron Kohl, Danny Allen, and Sarah Brown, Information Technology Division; Jocelyn Teh, Finance Division; and Barbara Schrack, Washington Office.

Electrotechnology Applications

New Approaches Hold Promise for Groundwater Cleanup

EPRI researchers are exploring two innovative applications of electrotechnologies to attack the costly and difficult problem of groundwater cleanup. One approach, using electromigration of dissolved chemicals, shows "very high promise," according to Ishwar Murarka, manager of EPRI's Land & Water Quality Studies Program. The other, which relies on electrokinetics to remove coal tar contamination, has potential but appears less likely to provide solutions in the near term. "Technologies like electromigration and electrokinetics are not complex, and they offer convenient, inexpensive, and potentially effective alternatives for groundwater cleanup," Murarka says.

Scientists at the University of Colorado at Boulder recently began field-testing the electromigration process following successful laboratory studies. The process may be suitable for removing sulfates, boron, chlorides, and, to a lesser extent, some toxic metals. According to Murarka, when there is groundwater contamination at utility coal combustion waste disposal sites, it most often involves sulfate and boron pollution. Although, in most cases, current regulations do not require removal of such pollutants, future regulations may address this area, he says.

In electromigration, electricity is applied at two locations using a pair of electrodes. Current moves from one electrode to the other, and, in that process, the flow carries pollutants in the water to the electrodes, where they concentrate and can easily be pumped to the surface.

Murarka expects to have results of the field tests later this year. Patenting the electromigration process is being investigated, and Murarka hopes the technology will be available for utility use in 1994.

"The process should be simple enough that no extensive hardware is required," Murarka says. "As a result, we expect many utilities will be eager to give electromigration a try."

Using the same two-electrode principles as in electromigration, researchers at Lehigh University are exploring the use of electrokinetics to remove coal tar contamination from groundwater. Lehigh's laboratory studies, jointly funded by EPRI and Illinois Power, are testing the ability of electric current to enable coal tar to flow through water toward an electrode, where it can be easily collected.

"Preliminary efforts have shown that coal tar can be much more difficult to deal with than we anticipated," Murarka says. "This is a feasibility study. If electrokinetics doesn't work, we'll look for other removal methods."

■ *For more information, contact Ishwar Murarka, (415) 855-2150.*

Nickel, Arsenic, and Chromium

Health Risks of Toxic Emissions Explored

Of the 189 toxic air emissions targeted by the Clean Air Act Amendments of 1990 for possible regulation, three—nickel, arsenic, and chromium—are of particular concern to electric utilities. EPRI's Environment Division has launched research to investigate the potential health risks associated with power plant emissions of these substances and to determine whether the current risk estimates used by regulatory agencies are relevant to electric utilities.

"The big question is, should we apply existing risk estimates, based largely on ore smelting or refining data, to power plant emissions of nickel, arsenic, and chromium?" research manager Larry Goldstein says. "The data are drawn from different processes, and the chemical species involved are apparently different from the compounds emitted by utility stacks."

To address these subjects, EPRI is funding a study at the University of Louisville on the comparative chemistry of nickel, arsenic, and chromium in fly ash. The final results are expected by this June—in time for consideration by the Environmental Protection Agency in its assessment of health risks from power plant emissions, an assessment required by the Clean Air Act Amendments.

The EPRI study is focusing first on nickel and then on arsenic—the two most important substances to utilities in terms of potential health risks and regulatory interest. Nickel is found in both coal and oil fly ash, and prolonged exposure to nickel-containing refinery dusts is associated with an increased incidence of cancer. Arsenic, considered to be a human carcinogen, is present in coal fly ash.

Should risk analysis demonstrate that the forms of nickel, arsenic, and chromium emitted from power plants either are not hazardous or are much less hazardous than the substances on which current health risk assessments are based, then utilities would not be subject to regulation on that basis. "The study results may show no discernible health benefit from removing nickel, arsenic, and chromium emissions from power plants," says Goldstein. "Or, if controls are needed, the data will indicate how much of each substance must be removed and will aid the utility industry in developing engineering solutions."

■ *For more information, contact Larry Goldstein, (415) 855-2725.*

Power Quality

Superconducting Storage May Keep BART Trains Running

The use of mass transit in the San Francisco Bay Area has increased significantly since the inception of the Bay Area Rapid Transit (BART) system 20 years ago. And with today's high levels of transit and electrical system loading, the system occasionally experiences voltage sag.

Much as water pressure drops in a home's pipes during heavy use, the voltage sags or drops on BART's dc electrical system as the power draw increases. This problem causes train motion to become jerky for a few seconds in the 3.4-mile submarine line under the San Francisco Bay (where the substations are located far apart, on the opposite sides of the bay). "The more trains that accelerate in the transbay tube, the lower the voltage gets," says Robert Schainker, EPRI's program manager for energy storage. "If the pressure gets below 750 volts, the BART train cars lose power." Not only does this cause discomfort and anxiety for passengers in this earthquake-prone region, but it causes additional wear on the traction power system.

In an effort to find solutions to this problem, BART has teamed up with Pacific Gas and Electric (which supplies the power for BART trains) and EPRI. Researchers from PG&E and San Francisco's Bechtel Group are exploring the option of using energy storage devices in the middle of the transbay tube to ensure that the voltage always stays above 750 volts during the occasional, brief periods of severe loading. One option under consideration is a superconducting magnetic energy storage (SMES) device. Although SMES technology has been used in laboratory settings for some time, the devices have become commercially available only in the last few years, Schainker notes.

"Superconducting magnetic energy storage has the potential to help utilities improve power quality in many customer applications," he says. "The BART case is only one example of how it may be best to serve customers with special reliability needs by locating small storage and generating systems on their own premises."

The SMES device being considered for BART could provide 3.2 MW of power for about 3 seconds. The device, which can be configured to fit into a section of the BART tunnel, stores electricity in a magnetic coil of superconducting wire. A cryogenic refrigeration system keeps the coil at liquid-helium temperatures to maintain the superconducting properties of the wire. The current in the coil generates a dc magnetic field that stores electric energy. The stored energy can be discharged rapidly through a dc-to-dc converter, which maintains electricity at 750 volts when voltage sag occurs.

"SMES has the potential for a faster response, a longer life, and a higher efficiency than conventional lead-acid battery energy storage systems, which are also being studied as an alternative answer to BART's problem," Schainker says. In addition, researchers will examine other conventional solutions, including installing a substation in the transbay tunnel.

Schainker anticipates that by the end of 1993, engineers will have a recommendation for solving BART's problem. The next steps will be to build a prototype for one or more of the solutions recommended and to evaluate each on the BART test track in Hayward, California.

■ *For more information, contact Robert Schainker, (415) 855-2549.*

Innovative Methods Could Help Restore Shad to the Susquehanna

Efforts to reverse the toll of a century of development, pollution, and overfishing could help restore large numbers of juvenile American shad to the Susquehanna River's upper reaches. During the fall outmigration, young fish must pass through the turbines of four hydroelectric dams on the river. EPRI has worked with Metropolitan Edison to demonstrate the effectiveness of a low-cost strobe light avoidance system at one of the dams—a system that repels shad from the turbine intakes and into a bypass sluiceway. In addition, plans are being made to test an acoustic repulsion system that would work in turbid water.

The multiyear study of the use of strobe lights was sponsored by Metropolitan Edison, the Susquehanna River Anadromous Fish Restoration Committee (representing various fish and wildlife agencies and the four hydroelectric project owners), and EPRI. EPRI selected the lights on the basis of information from a survey of state-of-the-art fish protection methods (EPRI report AP-4711) and from related work. A series of constantly operating lights positioned in front of the trash racks of the five units at the utility's York Haven hydroelectric station effectively repelled fish from the intakes. Meanwhile, the hourly activation of a second series of lights upon the opening of the sluice gate guided the congregated fish into the tailrace, allowing them to bypass the turbines.

Metropolitan Edison estimates that the strobe light approach could save at least $4.3 million from the cost of

upgrading the trash rack system and would avoid the additional costs associated with energy losses and increased maintenance. "This is the first case we know of where a downstream bypass system using strobe lights has worked so well," says Ronald Toole, president of Metropolitan Edison's York Haven Power Company. "This successful demonstration will enable us to pursue strobe lights as an alternative to costly upgrades of existing trash racks. Restoring shad runs to the Susquehanna will have great value to sport fishermen in the area."

Other utilities with hydro dams are now exploring strobe lights in configurations specific to their facilities as part of plans to install fish bypass systems. EPRI is also planning to work with Metropolitan Edison and with Pennsylvania Power & Light's Holtwood station on the Susquehanna to evaluate an underwater acoustic signal generator for use in turbid water, where strobe lights may be less effective.

■ *For more information, contact Charles Sullivan, (415) 855-8948.*

Design Guide Helps a Customer Maximize Load-Shift Benefits

Like many utilities these days, TU Electric offers incentives to business and industrial customers to shift major loads to off-peak hours, thereby shaving some of the utility's peak demand. When Texas Instruments, one of the utility's major industrial customers, recently wanted to reduce the cost of operating a 4200-ton cooling system at a large electronics plant (over a million square feet), TU Electric helped the company identify thermal storage as the most cost-effective candidate technology.

But what really convinced the customer was information contained in EPRI's *Stratified Chilled-Water Design Guide* (EM-4852). Information provided by the guide and TU Electric addressed all of Texas Instruments' questions about the technology and helped the company decide to install a 2.7-million-gallon stratified chilled-water storage tank that shifts over 3500 kW of load by chilling water during off-peak hours for use in space conditioning during the day. The guide provided technical data indicating Texas Instruments could achieve a 19% return on investment and maximize the benefits of the $175/kW load-shift incentive offered by TU Electric. In addition to the demand shift, the system also shifts an average 20,000 kWh daily to off-peak periods, further improving system load factor. TU Electric expects a benefit of $3.2 million from the Texas Instruments installation and potentially an additional $74.9 million from thermal storage installations at other large customer facilities that

Tracer Leak Detector Goes to Work in the Real World

Consolidated Edison Company of New York operates one of the largest underground transmission and distribution systems in the world, including the longest lengths of pipe-type, fluid-filled transmission cable. In such a dense urban area as New York City, underground leaks of dielectric fluid from such cables can be costly and difficult to find and repair. Recently, however, Con Edison proved the effectiveness of a new leak detection system that sniffs out vapors of a tracer chemical to quickly and accurately locate pipe-type cable leaks. Until now, in the event of a small leak, the utility has had to deenergize a cable and conduct a time-consuming and labor-intensive search using flow-direction sensors at pipe casings or freezes to find the section to be inspected and repaired.

In the new method—developed at Brookhaven National Laboratory in a project funded by EPRI, Empire State Electric Energy Research Corporation, and Con Edison—dielectric fluid that is chemically tagged with a low concentration of perfluorocarbon tracers is injected into a pipe. Vapors of the stable, nontoxic, nonpolluting, and non-ozone-depleting substances are readily detectable in the soil or atmosphere near a leaking cable—at parts-per-quadrillion concentrations—because they are little used commercially. Russell Dietz, head of the tracer technology center at Brookhaven, directed the effort. Underground Systems, Inc. (USI), developed the special injection system that was used to introduce the tracer into the pipe for the Con Edison demonstration. USI now has an EPRI license to provide this service to utilities.

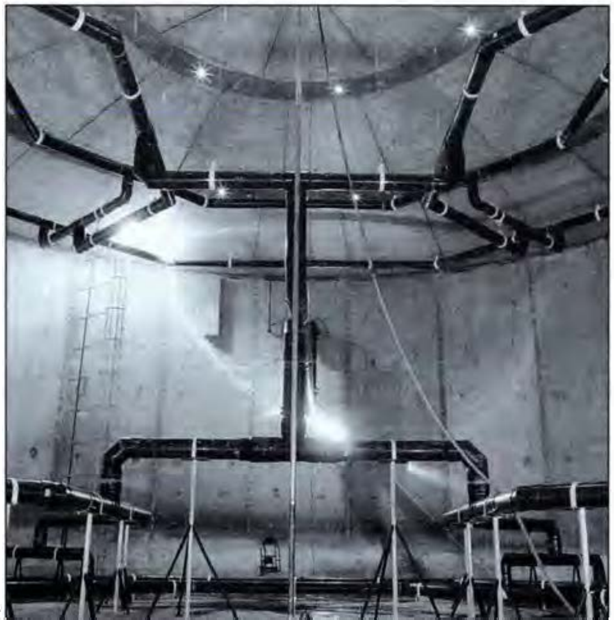
In its first trial in a real-world situation, the method worked as intended, allowing Con Edison to keep a 138-kV double-circuit feeder in service while crews located a 1-gallon-per-hour leak on a 3000-foot section of the cable pipe. Such a low-volume leak normally could have taken many days to find, but in this case crews were able to pinpoint the leak to within 1 foot of its actual location within a few days. "It was a very successful test, although on a relatively short feeder," says Reza Ghafurian, manager of Con Edison's transmission research program. "The main advantage of the technique is that we were able to conduct the entire operation without deenergizing the feeder. We are planning to try the method next on longer sections of pipe-type cable."

■ *For more information, contact Phil Garcia, (914) 964-2976.*

could result in peak demand shifts of 75–100 MW in the coming years.

The system at Texas Instruments has operated so successfully since it was installed in 1990 that the company is installing a larger system at another plant and is considering other applications. "During its first year of operation, the system was 100% reliable, and its performance and savings exceeded our expectations," says Don Fiorino, an engineer with Texas Instruments. "As a result, we've recently begun another large thermal energy storage retrofit project, based on the original design concept, at a second manufacturing plant."

■ *For more information, contact Ron Wendland, (415) 855-8958.*



Contributors

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Stephen Chapel, manager of energy storage economics in the Generation & Storage Division, joined the Institute in 1980 after four years as a senior economist with the Rand Corporation. Before that, he was deputy director of the U.S. Department of Energy's Office of Economic Impact. Chapel received a BS in statistics and an MS in economics from the University of Wyoming.

Jeremy Bloom, manager of the Integrated Energy Systems Division's Integrated Resource Planning Program, joined the Institute in 1992 after a decade of work for General Public Utilities, where he most recently served as manager of demand-side planning. Previously he taught operations research at Cornell University for four years. Bloom has a BS in electrical engineering from Carnegie Mellon University and MS and PhD degrees in operations research from the Massachusetts Institute of Technology. ■

EMF in American Homes (page 18) was written by science writer John Douglas with information from members of EPRI's Electrical Systems Division.

Karl Stahlkopf became the director of the Electrical Systems Division early in 1992. He previously directed the Nuclear Power Division's Safety and Reliability Department and from 1980 to 1989 headed that division's Systems and Materials Department. Stahlkopf came to EPRI in 1973 after seven years in the Navy, where he specialized in nuclear propulsion. A University of Wisconsin graduate in electrical engineering, he also holds MS and PhD degrees in nuclear engineering from the University of California at Berkeley.

John Dunlap has been manager of the Electrical Systems Division's magnetic fields research since 1991, and he also worked in the EMF area at Florida Power & Light from 1987 to 1990. Dunlap had been employed by both organizations previously, having worked in EPRI's Overhead Transmission Lines Program between 1979 and 1987 and as an engineer at FP&L for over 20 years before that. He received a BS degree in electrical engineering from the University of Tennessee. ■

Videoconferencing: Face to Face at a Distance (page 26) was written by Judith Quinn, senior communications consultant for EPRI's Information Technology Division, with assistance from several other members of that division.

Marina Mann, as vice president, information technology, is responsible for the strategic planning, positioning, and management of the Institute's corporate information technology and for the electronic technology transfer of EPRI research products to the utility industry. Before joining EPRI in 1984, Mann held positions as vice president of central systems at Wells Fargo Bank and vice president of computer systems at the Federal Reserve Bank of San Francisco. Her experience also includes work in the international pharmaceutical industry and at the Rand Corporation. Mann is a graduate of the University of New Mexico.

Ron Kohl, manager of advanced technology assessment and integration, has worked in all areas of information technology, including applications development, systems programming, network management, and strategic planning. Since coming to EPRI in 1988, he has been primarily involved in the development and implementation of EPRINET, the Institute's on-line information system. Previously he was director of telecommunications for a large multinational retail firm. Kohl has a BA in economics from San Jose State University.

Danny Allen, a network architect/designer with 14 years in telecommunications, is the division's manager of network implementation and support. Before joining EPRI in 1991, he worked as a consultant for the Institute and for the financial and computer manufacturing industries in the United States and Asia. Allen earned a BA in economics from Swarthmore College. ■

Fossil Plant SO_2 Control

FGD Materials Guidelines and Software

by Paul Radcliffe, Environment Division

Over the past 10 years, EPRI has committed a substantial portion of its annual research budget in the area of flue gas desulfurization (FGD) to the investigation and resolution of problems with the materials of construction used in FGD. Results from extensive laboratory and field tests of candidate materials, as well as from failure investigations, have been published in over 30 EPRI reports.

A research project has recently been completed that consolidates this information into guidelines for FGD materials selection, specification, installation, and maintenance. These guidelines have been designed to help utility personnel screen alternative materials of construction and select the most effective methods for protecting FGD components and the flue gas path from corrosion and erosion. The full range of materials used in FGD are covered, including organics, inorganics, and metal alloys. An ad hoc project advisory committee composed of utility personnel knowledgeable in materials and corrosion protection participated in a review of the project results.

Personal computer software was developed as a supplement to the guidelines manual. A database provides easy access to information on experience with materials at many of the currently operating FGD facilities in the United States. The database allows the user to conduct customized searches for data on materials performance, maintenance practices, and costs. There is also an economic model for computing life-cycle costs of alternative materials for FGD components. In addition, a bibliographic database provides abstracts of over 600 published articles and research reports related to FGD materials of construction.

FGD materials survey

To obtain information on materials performance, maintenance practices, and installed costs, questionnaires were sent to utilities that operate FGD systems. Where materials problems were revealed, careful attention was paid to documenting the reasons for failure, failure mechanisms, and successful remedies. As much detail as possible was obtained regarding the operating environment, including temperature, chemistry, and physical characteristics. System suppliers and architect/engineers made recommendations on materials selection and maintenance practices and supplied estimates of installed costs. Materials suppliers provided information on maintenance requirements, expected service lives, installation procedures, environmental limitations, and installed costs. Approximately 100 companies responded to the survey, including 39 utilities, 5 FGD system suppliers, 2 architect/engineers, 22 materials suppliers, and 24 component suppliers. In addition to these U.S. companies, 7 European and Japanese companies with FGD experience provided information.

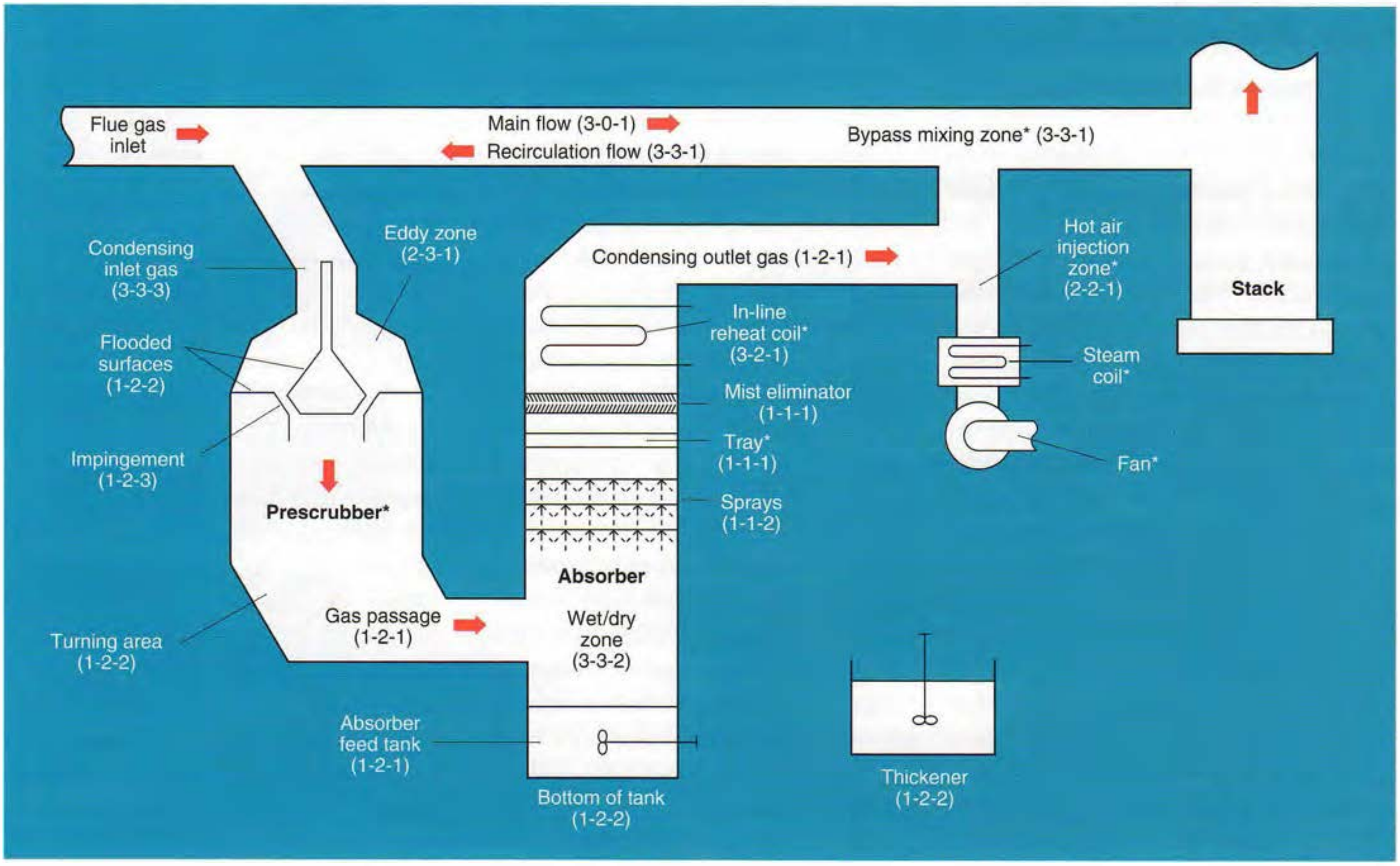
EPRI's materials research was another important source of information for this study. The project team drew on the large body of EPRI reports and guidelines related to FGD materials of construction, as well as on results from ongoing EPRI-sponsored laboratory and field studies. Information was also obtained from Battelle's in-house database on FGD systems (which includes data from trip reports).

The results of this effort have been incorporated into a recently published two-volume EPRI report, *Guidelines for FGD Materials Selection and Corrosion Protection* (TR-100680). This manual is designed to help the electric utility industry identify successful materials, determine why materials fail in certain applications, and develop materials-related operation and maintenance practices for improving FGD system reliability. Included are descriptions of commercially available materials, designated by supplier, manufacturer, trade name, method of application, and cost. The guidelines are applicable to the installation of FGD systems on new or existing units, as well as to the upgrading of existing FGD facilities.

A key element of the guidelines is a de-

ABSTRACT *Corrosion and erosion have been important causes of failure and shutdown in first-generation flue gas desulfurization (FGD) systems. A wide variety of construction materials have been used, and new materials are continually being tested and applied, with varying degrees of success. EPRI has developed guidelines and software to assist utilities in the selection, specification, installation, and maintenance of corrosion-resistant materials. The guidelines incorporate results from a survey of nearly all operating U.S. FGD facilities, plus results from EPRI research on FGD materials and corrosion protection. Other tools include a database on FGD materials experience, a computerized bibliography of materials research, and a model for computing life-cycle costs of alternative materials.*

Figure 1 Environmental severity levels in wet FGD systems, as designated by ASTM codes. The first digit in a code represents temperature, the second chemistry, and the third abrasiveness. The mildest set of conditions (e.g., mist eliminator zone) is coded 1-1-1. The most severe (venturi prescrubber inlet) is coded 3-3-3. A zero indicates that the factor is not applicable. Components or zones marked by an asterisk are optional.



cision logic for materials selection. The decision path leads the user through a step-by-step process for selecting suitable materials for a given application. At each decision point in the path, the user will be directed to the appropriate section of the manual for pertinent information.

The guidelines also address corrosion protection techniques, including successful maintenance practices, modifications to the environment, and corrosion monitoring. The results of the survey are broken down by component (or area).

Software tools

Included with the guidelines manual are diskettes containing a computerized database on materials experience at the FGD installations in the survey—138 individual FGD systems at 84 U.S. power stations. The database is divided into three sections, which present background information, materials performance data, and materials maintenance and cost data. FoxPro 2.0 is the database management system.

The background information section describes plant operating characteristics, including the coal's sulfur level, the chloride concentration in the scrubber slurry liquor, the type of flue gas reheating, and the water balance. The materials performance section describes the material currently being used, the original material, the service life, and the reasons for failure. The maintenance and cost section presents maintenance practices, installation costs and time requirements, and annual maintenance costs. Operation and maintenance practices have been found to have a significant effect on materials performance.

Users can perform a variety of searches and can customize the output presentation to highlight data and characteristics that are of interest. The three database sections can be searched individually or in combination to generate tables summarizing the extent of application of the various types of materials. For example, users who are interested in a particular material for their application can easily find out how many units are using that material, and in which areas of the FGD system. Users can also access specific plants to find out what materials are being used and how they have performed. Since experience has shown that materials may work well in some environments but not in slightly different ones, it is always prudent to access the background section for information on plant characteristics in order to clarify differences.

Some users may be interested in finding out where certain materials tend to fail most often. For example, the most failures with stainless steel have been found in outlet ducts and in the wet/dry zone of inlet ducts. The aggressiveness of an environment is dependent on temperature, chemistry, and abrasiveness. The American Society for Testing and Materials (ASTM) classifies each of these factors into three levels of severity—from 1 (mild) to 3 (severe), as described in Table 1. Figure 1 uses this classification system to identify the severity of the environment in the gas path and the major components of wet FGD systems. More information on each failure reported in the EPRI survey is presented in the materials performance section of the database.

The database can be used to break down materials applications in a variety of ways, such as by type of FGD system, type of reheating system, or type of water supply system (closed versus open loop). Materials performance can be correlated with system design, as well as with operation and maintenance practices.

An economic model included with the guidelines can be used to calculate life-cycle costs of alternative materials for FGD components. The calculation methodology conforms to EPRI's Technical Assessment Guide (TAG™) and employs specific design and economic criteria provided by the user. Projected service lives and the time value of money are used to determine the net present value and levelized annual costs associated with alternative candidate materials. The model can be used to run sensitivity analyses, in which the anticipated service lives and future replacement costs are varied, enabling the user to identify the alternative with the lowest life-cycle cost.

Another diskette included with the guidelines contains a computerized bibliographic database on FGD materials R&D, which has over 600 citations. The database can be sorted by title, author, document source, publication year, or language (10 languages are represented). Keyword searches can also be performed. About 460 citations are in English.

Table 1
ASTM CLASSIFICATION SYSTEM FOR ENVIRONMENTAL FACTORS

Level of Severity	Environmental Factor		
	Temperature	Chemistry	Abrasiveness
1	Ambient to 140°F (60°C)	pH >3 with <100 ppm fluoride and <1000 ppm chloride	Low-velocity fluid flow with no direct impingement of particulates (e.g., duct wall)
2	140–200°F (60–93°C)	pH of 0.1–6 with 100–1000 ppm fluoride and 1000–10,000 ppm chloride, or saturated flue gas	High-velocity fluid flow, spray impingement, or strong agitation (e.g., absorber spray zone)
3	Above 200°F (93°C)	>15% acid with >1000 ppm fluoride and >10,000 ppm chloride, or intermittent wet/dry zones	Very-high-velocity fluid flow with impingement of entrained particulates (e.g., venturi throat)

Major survey findings

The response of utilities to Phase 1 of the 1990 Clean Air Act Amendments indicates a trend toward the use of larger and fewer absorber modules, without spares, for flue gas desulfurization. This trend makes it even more important for a utility to properly select and protect the materials of construction. The information presented in EPRI's materials guidelines is designed to help utility engineers select and maintain materials that will achieve greater reliability and longer service lives. The guidelines, supplemented by the databases, provide a substantial resource base for those who need up-to-date information on the wide variety of materials being applied to FGD. The following paragraphs summarize the more significant findings from the guidelines.

The FGD outlet ducts represent one of the most aggressive environments for materials of construction. In this zone, residual sulfur dioxide and sulfur trioxide condense, forming an acidic condensate that attacks the surfaces. EPRI-sponsored failure cause investigations have revealed that operating with flue gas bypassed around the absorber modules, whether for emergency reasons or for flue gas reheating, can accelerate the degradation of materials in the mixing zone, where the scrubbed gas encounters the bypassed gas. Even the high-grade nickel alloys are subject to corrosion in this environment.

A wide variety of organic materials have been tried in FGD systems, including polyester, vinyl ester, epoxy, natural rubber, chlorobutyl, neoprene, fluoroelastomers, and fiber-reinforced plastic. Proper selection and application are critical to their longevity. Improper curing and improper seaming of joints are typical failure causes. Organics have a relatively low tolerance for temperature excursions.

Inorganics used in FGD systems include acid-resistant brick, borosilicate glass block, ceramic tile, concrete, and mortar. Often membranes are applied under the blocks and tiles for increased permeation resistance. Inorganics generally are better able to handle temperature upsets than organics and are insensitive to chlorides.

Alloys used in FGD systems include the 300-series stainless steels (commonly 316L, 316LM, 317LM, and, recently, 317LMN); the super-austenitics (such as AL-6X, AL-6XN, and 20Mo-6); the nickel-grade alloys (such as 625, 825, G, C276, and C22); and titanium. To get around the high cost of alloys, many utilities are either using mill-clad carbon steel plate or "wallpapering" thin alloy sheets onto carbon steel. (Wallpapering procedures are described in a recently released Standard Recommended Practice report from the National Association of Corrosion Engineers—*Installation of Thin Sheet Wallpaper Lining in Air Pollution and Other Process Equipment*, RP0292-92.) Alloys generally last longer than organics; however, a few failures have been reported where chloride limits were exceeded. Stringent quality control of welding is a must.

Chlorides are especially detrimental to the stainless steels, and fluoride can have a catastrophic effect on titanium. The selection of materials should take into account the potential for so-called regulatory ratchet: future regulations restricting plant water discharge may result in higher chloride levels in the FGD system.

Some manufacturers of expansion joints are offering less-expensive joints by mixing reprocessed fluoroelastomer scrap with virgin fluoroelastomer. There is some evidence that the reprocessed material may adversely affect the performance of the joint in hot acidic environments. Substitution of the reprocessed material is difficult to detect.

On-line corrosion monitoring has been successfully employed to help operators avoid unit operation in a critical corrosion regime.

Failure investigations

EPRI has a program in place to help member utilities determine the causes of materials failures in FGD systems. The program involves site visits for field evaluation of the material, laboratory analyses of samples collected in the field, and analysis of the data. In each case a report of the results of the analysis, including recommendations for remedying the failure, is issued to the host utility. Over 40 field investigations have been conducted over the past 10 years. Cofunding by the host utility is required. Any materials failure in a component of an FGD system is a candidate for failure analysis under this program.

For more information on either the failure investigation program or the FGD materials guidelines, contact Paul Radcliffe at EPRI, (415) 855-2720. The guidelines (including the software diskettes) are available from the EPRI Distribution Center, (510) 934-4212.

Fossil Plant Air Quality Control

Continuous Emissions Monitoring

by Charles Dene and Ruseli Owens, Environment Division, and Ellen Petrill, Generation & Storage Division

The continuous monitoring of air pollution emissions is one of the most immediate and complex requirements of the 1990 Clean Air Act Amendments (CAAA). Virtually all U.S. fossil-fuel-fired electric utility plants are now subject to legal mandates that enforce the continuous monitoring of emissions levels. Industrywide, the amendments require a total of more than 3000 continuous emissions monitoring (CEM) systems to be installed, certified, and operational in a relatively short period of time.

The Environmental Protection Agency (EPA) and many state regulatory authorities have implemented extensive technical and legal requirements for verifying compliance with emissions limits and for the reporting of emissions levels. Regulations resulting from the 1990 CAAA and published in 40 CFR 75 are initiating sweeping changes in the approach to emissions monitoring. First, a change in the monitoring focus for sulfur dioxide—from an emissions rate (lb/million Btu) to an emissions inventory (lb/h)—introduces a need for the direct measurement of large-volume gas flows from individual units. Second, the regulations tighten the relative accuracy requirements and, by instituting a punitive approach to the reporting of missing data, enforce a high level of data capture. These changes place greater emphasis on the need for utilities to select accurate and dependable CEM systems.

The effect of all this on the utility industry will be sizable. By 1995 the industry will spend between $2 billion and $3 billion to implement the monitoring requirements of the 1990 CAAA. It is also important to understand that the monitoring requirements under 40 CFR 75 do not replace existing monitoring requirements, nor are the data-handling and -reporting requirements consistent with existing regulations.

Monitoring guidelines

In the early 1980s, EPRI developed a CEM guidelines manual to assist its member utilities in selecting, operating, and maintaining CEM systems for complying with the federal and state monitoring regulations then in effect. It revised the manual in 1988 to cover the more stringent CEM requirements proposed under the New Source Performance Standards (40 CFR 60, Subpart Da and Appendix F). This revision was published as *CEM Guidelines: Update* (CS-5998).

EPRI is currently revising these guidelines to reflect the new 40 CFR 75 regulations. For utilities needing interim information, EPRI's contractor, Kilkelly Environmental Associates, has prepared an addendum to the guidelines that reviews the regulations and presents recent information on monitoring technologies, including flow monitors. The addendum can be ordered by contacting Nancy Spinelli at (415) 855-2466.

Utility and vendor databases

The CEM Databases, another EPRI product for helping utilities comply with the 1990

ABSTRACT *The 1990 Clean Air Act Amendments require the installation of continuous emissions monitoring (CEM) systems at virtually all U.S. fossil-fuel-fired utility plants. Moreover, regulations resulting from the amendments are initiating broad changes in the approach to emissions monitoring and reporting. Building on the CEM research it has conducted for over a decade, EPRI is sponsoring a variety of projects to help utilities understand and deal with this complex issue. Products include guidelines for implementing successful CEM programs, software for managing emissions reporting at the corporate level, and engineering models for evaluating flow-monitoring locations.*

CAAA, were released in January 1992. Available from EPRI's Electric Power Software Center, these two databases were developed in dBase IV for use on IBM-compatible personal computers. The utility database contains historical data from a survey of utilities with coal-fired units and reflects industry experience with specific CEM systems. The vendor database lists commercially available CEM equipment and presents equipment descriptions and costs from selected vendors.

The databases will be revised twice a year in order to keep up-to-date on CEM systems purchased in the near future. (In the next two years, utilities that have Phase 1 and Phase 2 units as defined in the 1990 CAAA will be installing CEM systems.) The databases will help utilities reduce the time and effort spent in researching CEM systems. The topics covered include availability, accuracy evaluation, control and data-reporting systems, chronic problems encountered, overall system ratings, costs, sample-conditioning requirements, and warranty and customer service provided by vendors.

Flow monitoring

The requirement to monitor flue gas flow rate introduces a new area of effort for utilities. To date, there is little long-term industry experience in the measurement of flue gas flow in large utility ducts.

With performance monitoring as the focus, EPRI has worked with both Potomac Electric Power Company (PEPCO) and Sierra Pacific Power Company to test acoustic flow monitors in the stacks of coal-fired power plants. Flue gas flow rate is a key measurement for calculating heat rate with the output/loss method, which does not require on-line fuel flow measurement and is more accurate and less sensitive to measurement errors than other heat rate calculation methods. Both acoustic and ultrasonic devices were tested, and both were shown to be capable of meeting the 1990 CAAA flow-monitoring accuracy requirements, as well as providing a critical input for on-line heat rate determination.

In addition to acoustic flow monitors, two other basic flow-monitoring technologies are commercially available today: differential pressure and thermal. All these methods have been tested recently in utility CEM applications and have proved able to measure flow and meet the CAAA accuracy requirements. None may be suited to all applications, however; each has different strengths and weaknesses, depending on such factors as measurement location, stack or duct configuration, and process layout.

Although the flow-monitoring work at PEPCO and Sierra Pacific has given the industry an experience base in acoustic monitoring, these tests represent nearly ideal situations. In both cases, flue gas flow was monitored in circular stacks at a high elevation, where the flow was fully developed and well characterized. Since many utilities do not have the opportunity to monitor flow in such a location, EPRI has begun a project to develop guidelines for utility use in selecting approaches and duct or stack locations for flow monitoring.

Because of the urgent time requirements of the new CEM rules, this project is offering an intermediate deliverable: a database of utility experience in flow monitoring, including relative accuracy test audit (RATA) results from various types of flow monitors and in various stack or duct configurations. The first version of the database was released in March 1993. An expanded version with additional utility data will be released later this year. The database provides utilities an opportunity to analyze flow-monitoring data as needed for their own applications.

Another facet of the project is to evaluate numerical modeling as a tool for selecting flow monitor locations. A flow monitor is ideally located where the flow is most uniform across the duct or stack and over the load range of the unit. Identifying such locations requires characterization of the flow in the duct or stack. Numerical modeling provides graphic representations of the flow throughout the duct or stack that could substitute for expensive flow characterization tests. In these tests, typically conducted by contractors, S-type pitot tubes and three-dimensional pitot probes are used to traverse the ducts in multiple locations. The tests are difficult to conduct with consistent accuracy. Numerical modeling could reduce the cost, time, and potential errors associated with such manual flow characterization.

The findings and methods developed in this project will be documented in the form of guidelines utilities can use in selecting measurement locations and flow-monitoring approaches for numerous configurations. The guidelines will be available late this year. Utilities with Phase 1 units will most likely specify flow monitors before the project is completed, and those with Phase 2 units may be specifying monitors near its completion date, if not before. Once completed, however, the guidelines will provide assistance to utilities that have not yet selected flow monitors, are adding new units, or are opting to replace original flow monitors with new equipment.

Reporting software

Another EPRI product, the CEM Reporting Workstation, will assist utilities with the corporate management and reporting of emissions data. The workstation can generate corporate emissions reports for the EPA, as well as custom reports and emissions-monitoring plans, and can electronically submit reports to the EPA. It runs on IBM-compatible personal computers with Microsoft Windows. The software uses Microsoft Excel to generate the reports and Pioneer Q+E to access a utility's central database containing CEM data from each of the utility's power plants. Utilities have the option of using a variety of database management systems in a network. The database management system can reside on a mainframe, minicomputer, or microcomputer acting as a server so long as the standard CEM Reporting Workstation format is incorporated.

The workstation can be used in a distributed computing environment where many users access the read-only central database. It will enable a utility to produce custom reports and graphs for its own needs as well as to create ASCII reports in the format required by the EPA. Reports can be transmitted to the EPA via EPRINET and its gateway to Internet and the EPA mainframe.

Support services for the CEM Reporting Workstation include a users group, startup assistance, and software support. The users group is sponsored by EPRI and its commercializer, Electric Software Products, Inc. The group meets three times a year to discuss EPA regulations and to review software modifications or enhancements. All group members receive newsletters, updates to the software, and access to the CEM Reporting Workstation telephone hotline.

To ensure successful workstation startup, a "jump-start" consulting program is being provided by Electric Software Products and its subcontractor, Kilkelly Environmental Associates. Services include installation supervision, startup testing, and training in software use.

Software support is provided to assist with the integration of the CEM Reporting Workstation into the existing corporate environment; custom services to meet a utility's particular needs will be available. Software support may include writing detailed specifications for CEM report requirements, interfacing the workstation with databases, integrating it into various networks, and writing custom software components.

The CEM Reporting Workstation is available to EPRI members from the Electric Power Software Center and to nonmembers from Electric Software Products.

On-line forum

The CEM Forum, available through EPRINET, is designed to help member utilities keep pace with the rapidly changing developments in CEM. The forum is an electronic network of member utility personnel, EPRI staff, and selected EPRI contractors and consultants who share an interest in emissions monitoring. It provides up-to-date information about CEM regulatory and technology developments and about CEM-related events.

One main feature of the forum is the CEM News Service, which provides news articles in four areas: background information, recent news, CEM vendors and consultants, and regulatory activities. Another main feature is the CEM Bulletin Board, through which users can discuss CEM issues and exchange information with others in the industry and at EPRI.

Other monitoring developments

EPRI is working with Baltimore Gas & Electric on a project to evaluate the use of Fourier transform infrared (FT-IR) spectroscopy for the continuous monitoring of coal-fired power plant emissions. The primary purposes of the project are to establish the viability of this technology for monitoring emissions of sulfur dioxide, nitrogen oxides, carbon monoxide, and carbon dioxide and to design a mobile FT-IR emissions-monitoring laboratory. In addition, the study is assessing the ability of FT-IR techniques to measure the air toxics compounds identified in the 1990 CAAA.

In EPRI's Combustion Turbines Program, additional CEM efforts are under way to address some of the special technology features necessary for monitoring emissions from combustion turbines. Information on combustion turbine CEM experience will be incorporated into the CEM Databases, and information on ammonia monitoring will be incorporated into the new CEM guidelines.

Although the principles outlined in the existing *CEM Guidelines: Update* are still helpful, the utility industry is faced with complex changes in the approach to CEM. And time is critical: to meet the deadlines mandated in the 1990 CAAA, utilities must already be well along on the procurement and installation schedule. To provide assistance, the CEM guidelines addendum, the CEM Databases, and the CEM Reporting Workstation are available now. New CEM projects must focus on anticipated monitoring requirements to ensure that valid technologies are fully developed to meet future monitoring needs.

Exploratory Research

Biological Approaches to Reducing Atmospheric CO_2

by Sy Alpert, Office of Exploratory & Applied Research

The atmospheric concentration of carbon, in the form of carbon dioxide (CO_2), is increasing at a rate of approximately 3.5 billion metric tons (Gt), or 0.5%, a year. This increase is of concern to utilities because fossil fuel combustion is a contributing factor. Although the specific consequences of rising atmospheric concentrations of CO_2 and other greenhouse gases are still uncertain, attention is being focused on their potential economic and environmental impacts, and policies are under review that would mandate CO_2 control both internationally and domestically.

Over the past 10 years, EPRI has become increasingly involved in research to evaluate potential strategies for limiting atmospheric carbon burdens and to identify cost-effective systems for reducing that loading. EPRI's research program is structured to examine both conventional and unconventional options.

Research results indicate that the direct removal of CO_2 from power plant flue gas is a high-cost strategy. EPRI studies suggest that up to 35% of the electricity generated at a typical fossil-fuel-fired plant would be required to operate a CO_2 scrubber and transfer the liquefied captured gas to an ocean disposal site. The replacement of this capacity by non-fossil-fuel-fired plants or by clean coal technologies currently under development would be time-consuming and expensive; the resulting additional costs could increase the cost of electricity two to four times. In addition, the quantity of CO_2 produced in all fossil fuel applications worldwide is enormous—equaling 4.8 to 5.8 Gt of carbon annually—and it is difficult and expensive to dispose of captured CO_2 without its returning to the atmosphere.

Among the unconventional options for reducing atmospheric CO_2 being explored by EPRI researchers is the use of biological strategies to fix atmospheric CO_2 and sequester it naturally for extended periods. This approach shows economic promise, as indicated in Table 1, which presents cost estimates for various sequestering mechanisms, along with estimates for scrubbing and capacity replacement at pulverized-coal and integrated gasification–combined-cycle (IGCC) plants.

The rationale for employing existing CO_2 capture mechanisms to slow or halt the increase in atmospheric carbon is based on the fact that the increase, though large in absolute quantity, is very small when compared with the amounts of CO_2 that move naturally between the earth's oceans, atmosphere, and land. Figure 1 shows the quantities of carbon found in these three reservoirs and the approximate rates of carbon transfer between them. As can be seen, the yearly increase of about 3.5 Gt in atmospheric carbon is dwarfed by the approximately 105 Gt transferred from the atmosphere to the oceans and the approximately 110 Gt removed from the atmosphere by land-based green plants. Capturing the increased amount of atmospheric carbon either in the oceans or in land locations would involve raising the current transfer rates by only a few percentage points.

EPRI's Office of Exploratory & Applied Research (E&AR) is sponsoring three projects to investigate CO_2 capture and sequestering using ocean- and land-based mechanisms—algal refossilization, seaweed and halophyte cultivation, and controlled whitings. The objective of these projects, as well as of other work being performed by E&AR and various EPRI divisions, is to explore the potential of biological mechanisms to remove 1 Gt of atmospheric carbon annually.

ABSTRACT *As a strategy for moderating increases in greenhouse gases, the use of biological processes to capture and sequester atmospheric CO_2 may offer significant cost advantages over the direct removal of CO_2 from flue gas. EPRI's Office of Exploratory & Applied Research is evaluating the potential of three biological processes to sequester up to a billion metric tons of carbon annually. The results to date indicate that such approaches may be feasible, but much further work must be done before the costs and practical use of biological sequestering are established on a firm scientific basis.*

Algal refossilization of atmospheric CO_2

Algal growth is a natural sequestering mechanism that takes place along ocean coasts and in some midocean locations. In this process, CO_2 that has dissolved in the ocean to form carbonate and bicarbonate is absorbed by algae. After dying, noncalcareous algae (such as kelp) usually decompose and return the CO_2 to the atmosphere, but if these plants sink to a great enough depth (5000–6000 feet), they can remain undecomposed for an extended period. In the Sargasso Sea, for example, algae have been found virtually unchanged after more than 4000 years. When calcareous algae (such as coralline) die, the CO_2—in the form of calcium carbonate—remains sequestered indefinitely. A sample of calcareous algae is shown in the photomicrograph in Figure 2.

In an E&AR-sponsored project conducted by Neushul Mariculture, Inc. (RP8011-5), researchers are investigating the feasibility of developing large oceanic farms that would use algae to fix atmospheric CO_2. In such farms, "crops" of calcareous algae would grow on a floating "structure" of noncalcareous macroalgae, such as California kelp. Both types of algae would fix CO_2, and the high density of the growing calcareous algae would eventually sink the farms to the ocean floor.

One major advantage of this scheme is the low level of human participation required. After attaching the calcareous algae to the kelp, technicians would be required only to release the farm in a location that would allow it to float out to sea. Given the minimal labor expenses anticipated, overall costs are predicted to be extremely low.

Investigators have now demonstrated that, under the proper conditions, calcareous algae will reproduce in a laboratory. Immediately after the first algae were taken into the laboratory they released spores, and the resulting algae have been growing and propagating for over a year. This was a necessary step in determining the feasibility of algal refossilization because of various problems associated with the alternative of collecting spores from natural sources.

Another important step involves the development of a mechanism for attaching the spores to floating algae. Thus far, attachment to California kelp has failed because of enzymes and slime that the kelp manufactures for the specific purpose of preventing attachment by foreign bodies. As a result, researchers are investigating the option of attaching the calcareous algae to a degradable cotton fiber instead.

Seaweed and halophyte cultivation

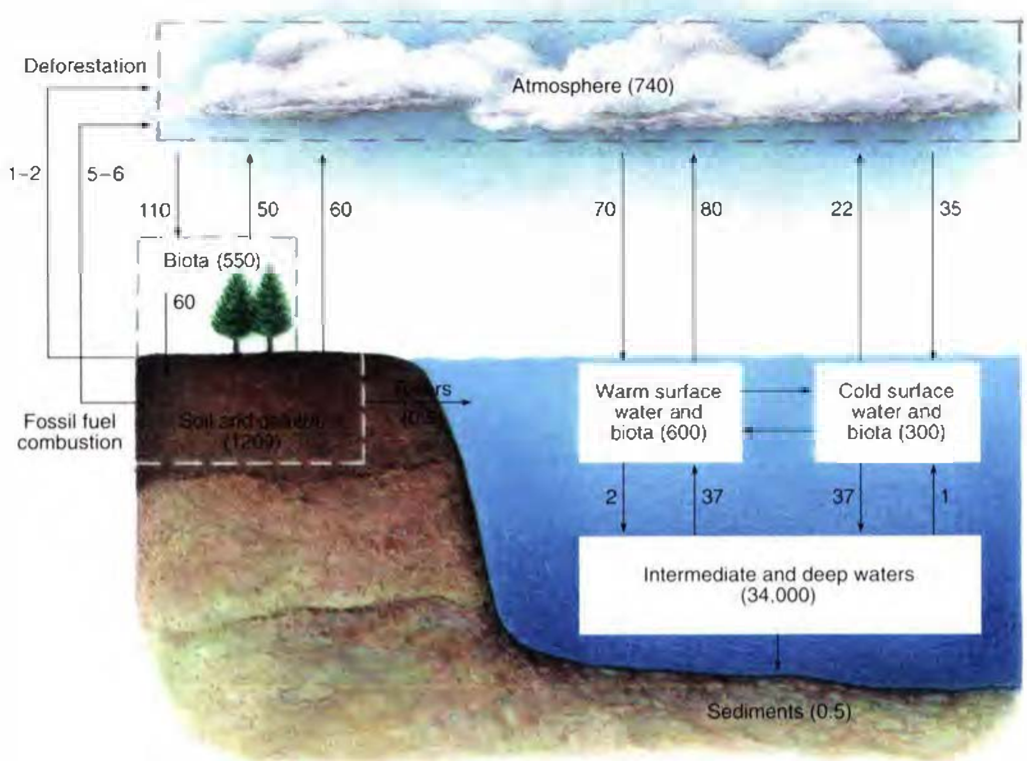
The use of seaweed and terrestrial plants to sequester CO_2 is an obvious option, given the fact that green plants assimilate CO_2

Table 1
ESTIMATED COSTS OF REDUCING ATMOSPHERIC CO_2

Method	Cost ($/ton carbon removed)
Flue gas scrubbing, plus capacity replacement by nuclear power*	
Pulverized-coal plant	230
IGCC plant	146
Flue gas scrubbing, plus capacity replacement by clean coal technology*	
Pulverized-coal plant	344
IGCC plant	174
Carbon sequestering	
Trees	60–120
Halophytes	100–160
Coastal seaweed	300
Open-ocean seaweed	150–300

*I.e., replacement of the electricity used in scrubbing and disposal operations.

Figure 1 Global carbon cycle, showing the major reservoirs (in Gt of carbon) and fluxes (in Gt/yr). A successful CO_2 sequestering system would need to increase the rate of carbon transfer from the atmosphere to the land and/or oceans by only a few percentage points. (Source: EPRI report EAR-7401.)



during photosynthesis. One proposal for increasing the amount of carbon stored in biomass is to initiate worldwide reforestation programs, but competition with other land uses makes such a strategy impractical.

Using seaweeds and halophytes (plants that grow in saline soils) to sequester CO_2 circumvents the land use issue because, unlike trees, these plants can be grown on continental shelves, coastal deserts, and inland salt deserts—areas that are little used for other purposes. In research cosponsored by the Salt River Project and E&AR (RP8011-3), scientists at the University of Arizona have investigated the sequestering potential of seaweeds and halophytes and compared the results with those for trees.

The research indicates that worldwide the shallow-water and land areas available for large seaweed or halophyte farms are comparable to the land available for reforestation and that projected yields of the three plant types are similar. As shown in Table 1, however, the cost of seaweed plantations was found to be prohibitive (approximately $300 per ton of carbon removed), given the present technological difficulties of working in the sea. In contrast, the estimated cost range for halophytes ($100–$160 per ton) overlaps that for trees ($60–$120 per ton).

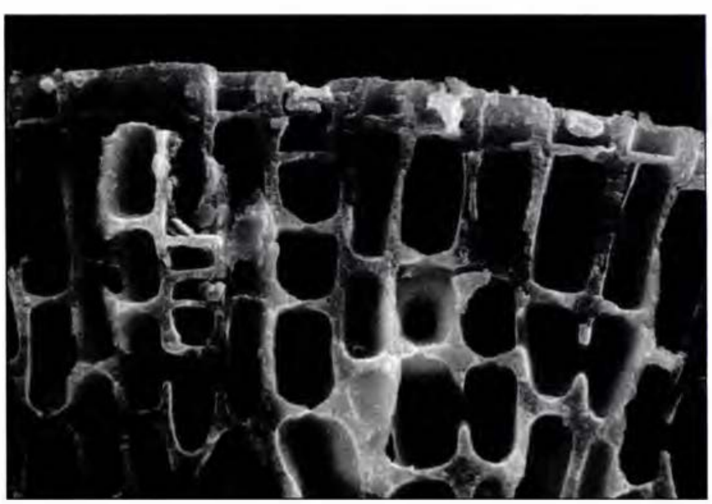


Figure 2 Photomicrograph of calcareous algae. The fossilization of such algae is one process being investigated as a way to sequester atmospheric CO_2.

Long-term storage, which is an issue with any biomass crop, was also considered in the study. The findings indicate that beyond the high cost of seaweed production, difficulties in storing seaweed carbon also make this method of CO_2 sequestering impractical. Although some seaweed carbon might be stored in ocean sediments, many seaweeds either float or sink slowly. It was determined that extensive decomposition will likely occur before a sufficient depth is reached for long-term sequestering. The possibility of sequestering halophyte carbon in desert soils was found to be practical, even if it turns out that transporting the biomass to dry soil is required in order to prevent rapid decomposition. As an additional benefit, according to the study, plowing the biomass back into the desert has potential for improving local soil quality and thereby increasing the amount of arable land.

On the basis of these results, investigators have continued the halophyte research to measure the growth rates and the resource and energy requirements for halophytes and to evaluate the potential of storing carbon in desert soils. The study site is a halophyte farm that has been established in Mexico on the coast of the Gulf of California. Two crops were harvested and plowed back into the desert in the fall of 1992. Measurements of yields and of halophyte carbon content at harvest were made. The buried biomass is being periodically sampled to determine its stage of decomposition and provide an estimate of the release of CO_2 back into the atmosphere. Decomposition rates are being determined at dry and at irrigated sites.

Controlled whitings

For decades in parts of the Caribbean and in warm waters near the Philippines, oceanographers and marine scientists have observed phenomena known as whitings, in which clouds of calcium carbonate precipitate spontaneously in the open ocean. Research has revealed that whitings involve a natural biological process that is nucleated by algae. After the process has begun, the algae become encased in the precipitated calcium carbonate and sink to the bottom of the ocean as "snowflakes" that become sediment.

The change in CO_2 partial pressure resulting from the precipitation then causes more CO_2 to be absorbed by the ocean. The process is self-propagating until the whitings approach land and the water's alkalinity changes enough to halt the process. In general, whitings last from two days to two weeks. Little is known about the ocean chemistry that causes the clouds to appear.

In a project to evaluate whitings as a means of sequestering CO_2, E&AR-sponsored investigators at the University of Southern Florida (RP8003-31) are seeking to characterize the types of algae and the ocean conditions necessary for whitings to occur. Goals of the project, which began in December 1991, are to culture and grow specific algae, elucidate the mechanisms of whitings formation, and identify areas (in addition to those already known) where the ocean chemistry is conducive to whitings formation. On the basis of such fundamental science, it may be possible to develop a practical approach to controlling whitings formation.

Other research

In addition to sponsoring the three projects discussed above, the Office of Exploratory & Applied Research is working with various EPRI divisions to investigate other posible means of reducing atmospheric CO_2 levels.

In a project at the California Institute of Technology (RP8011-14), researchers are investigating CO_2 solubility and the formation of clathrates—complex mixtures of CO_2 and seawater that are solids at deep-ocean pressures. Project results will enable the researchers to evaluate the feasibility of directly sequestering CO_2 in the ocean by pumping it to a depth below 500 meters.

Research is also being conducted by Energy Performance Systems to evaluate fast-growing trees as a means of sequestering CO_2 (RP2612-12 and RP3295-4). In addition, scientists are investigating the feasibility of harvesting these trees and burning them to generate electricity—thereby substituting biomass fuels for conventional fuels.

Nuclear Safety

Seismic Verification of Nuclear Plant Equipment

by Carl Stepp and Robert Kassawara, Nuclear Power Division

ABSTRACT *Under NRC mandate, utilities must verify that the equipment in older nuclear plants is capable of meeting current seismic standards. To fulfill this requirement in a cost-effective way, EPRI and the affected nuclear utilities have developed a methodology for evaluating the seismic adequacy of equipment on the basis of an experience database developed from existing test data and from data on actual equipment performance in earthquakes. This approach is being extended for application to replacement equipment and is being incorporated into industry standards. It promises to offer substantial savings in ongoing O&M costs for seismic qualification.*

In recent years, nuclear plant operation and maintenance (O&M) costs have generally risen at a rate considerably higher than the rate of inflation. A number of factors have contributed to this rapid cost escalation, including new regulatory requirements, the aging of plants, and a decrease in the number of companies offering specialized, qualified nuclear plant equipment. These developments threaten the ability of nuclear utilities to control O&M costs while maintaining safe and reliable operation of their nuclear units.

One activity that is placing severe cost burdens on nuclear utilities is the seismic qualification of equipment. This includes the one-time qualification of equipment in older nuclear units and the ongoing qualification of new and replacement equipment.

In the past, equipment for nuclear plants typically was seismically qualified by suppliers by means of testing or analysis. The suppliers implemented quality assurance controls that utilities depended on for a continuing supply of qualified replacement items. Today many suppliers no longer maintain quality assurance programs. This development has made it necessary for utilities themselves to assume responsibility for verifying the seismic adequacy of new and replacement equipment.

Evolving seismic regulations have had an even greater impact. The Nuclear Regulatory Commission has imposed a requirement on utilities to demonstrate that equipment in older nuclear units is capable of meeting current standards. This requirement, established as NRC Unresolved Safety Issue A-46, affects 70 nuclear units designed before the adoption of the current seismic regulations in 1974.

Since 1982, EPRI has been working with

the affected utilities, organized as the Seismic Qualification Utility Group (SQUG), to develop cost-effective procedures to address USI A-46. This effort has resulted in the development of a methodology for seismically evaluating equipment on the basis of an experience database that incorporates existing test data and data on actual equipment performance in earthquakes. To help utilities implement this methodology—called the SQUG Generic Implementation Procedure (GIP)—EPRI and SQUG researchers have provided application guidelines and have developed and held training courses for utility personnel. Also, the database of equipment that has been qualified by testing or has experienced real earthquakes has been commercialized. These products are making it possible for nuclear utilities to resolve USI A-46 rapidly and cost-effectively. Moreover, they promise to substantially reduce ongoing O&M costs for the seismic qualification of new and replacement equipment in the A-46 plants.

GIP methodology

The GIP methodology (accepted by the NRC) is based on two assumptions. The first is that the use of earthquake experience and generic seismic test data is an acceptable alternative to the qualification of equipment by analysis and component-specific testing. The second is that equipment seismic adequacy can be verified through a well-planned and -executed evaluation of a nuclear unit (called a walkdown) conducted by experienced earthquake engineers and aimed at verifying as-designed conditions.

From these assumptions came the steps for creating the essential elements of the GIP: defining generic classes of nuclear plant equipment for which adequate earthquake experience and generic seismic test data are available, developing an experience database for use in seismic adequacy assessment, establishing generic earthquake ground motion spectra that conservatively represent the earthquakes in the database, and developing seismic verification procedures.

The development of the earthquake experience database was made possible by two important circumstances. First, the equipment commonly used in nuclear plants is widely used in other power and industrial facilities. These types of facilities were surveyed to compile the database:

- Fossil fuel power plants
- Hydroelectric power plants
- Electric distribution stations
- Petrochemical plants
- Water treatment plants
- Water pumping stations
- Oil and natural gas pumping stations
- Manufacturing facilities
- Large industrial/manufacturing facilities
- Commercial facilities

Second, though earthquakes occur rarely at any given location, worldwide more than 100 earthquakes large enough to provide usable data occur each year. Many of them affect populated areas, where power and industrial facilities are located. Thus by collecting data worldwide, it was possible to compile, in a relatively short time, an adequate database to seismically evaluate the 20 classes of electrical and mechanical equipment shown in Table 1.

Table 1
EQUIPMENT CLASSES IN THE EARTHQUAKE EXPERIENCE DATABASE

Motor control centers
Low-voltage switchgear
Medium-voltage switchgear
Transformers
Horizontal pumps
Vertical pumps
Fluid-operated valves
Motor-operated valves
Fans
Air handlers
Chillers
Air compressors
Motor-generators
Distribution panels
Batteries and racks
Battery chargers and inverters
Engine-generators
Instrument racks
Temperature sensors
Control and instrumentation cabinets

The earthquake experience database is the result of studies of equipment at more than 100 power and industrial facilities that experienced strong ground motions in 19 large earthquakes. A criterion for including a facility was that it experienced local ground shaking greater than about 0.20g. Most nuclear plants are designed for motions ranging from 0.10g to 0.25g. Hence the equipment included in the database has typically experienced seismic motions larger than those for which the majority of nuclear units are designed.

The 20 broad classes of equipment listed in Table 1 represent the equipment in nuclear power plants that is important for safe shutdown. Two general guidelines were used in classifying the equipment. First, each class encompasses the broadest range of equipment included in the experience database. For example, the horizontal pumps class includes motor-driven pumps, since they are similar in general construction to the other pumps in the class. Second, an equipment class includes all components typically attached to the same enclosure or skid; equipment that is normally attached to larger equipment is not addressed separately. For example, the class of control and instrumentation cabinets covers all components typically found in such cabinets—including switches, relays, gages, dials, and recorders.

At each facility surveyed, researchers took photos and collected information on the performance of specific equipment. They also gathered data on the general effects of the earthquake motion, the characteristics of the equipment (for example, vintage, condition, and anchorage), and the equipment's location within its host structure. In addition, they collected data on seismic and other design conditions and gathered design drawings of structures, equipment, and systems. They developed and used standard procedures for surveying facilities and recording equipment performance. These procedures ensured that all information on damage or adverse effects caused by earthquake shaking was collected. The researchers found that except for sites that experienced very high levels of shaking (in excess of 0.50g) or in cases where equipment was improperly installed, damage to seismically designed, well-engineered facilities was normally minor.

Use of the experience database in verifying the seismic adequacy of equipment in a nuclear plant requires that the seismic shaking experienced by equipment in the database equal or exceed the plant's seismic design basis motions. Earthquake motions experienced by the database facilities were carefully cataloged. From those motions, a generic spectrum was developed that conservatively represents the composite motions experienced by the equipment at the database sites. This generic earthquake spectrum, shown in Figure 1, represents the lower bound of the seismic capacity of similar equipment in nuclear power plants. Similarly, for a given equipment class or subclass, a generic ruggedness spectrum (GERS) was developed that represents the composite test spectra to which the seismically tested components included in the database have been qualified. In order for the experience database to be applicable to the equipment in a given nuclear plant, the plant's design basis response spectrum at the equipment's location must fall below the generic experience-based spectrum or the relevant GERS.

Typically a class of equipment covered by the database has experienced a wide range of earthquake motions, including both nondamaging and damaging motions. The database catalogs each earthquake experienced by the class, noting the motion level and any resulting damage. This information makes it possible to establish a conservative determination of the seismic ruggedness of the equipment class. For example, the inventory for the batteries and racks class shows that this class can reliably be qualified for motions up to about 0.45g (Figure 2).

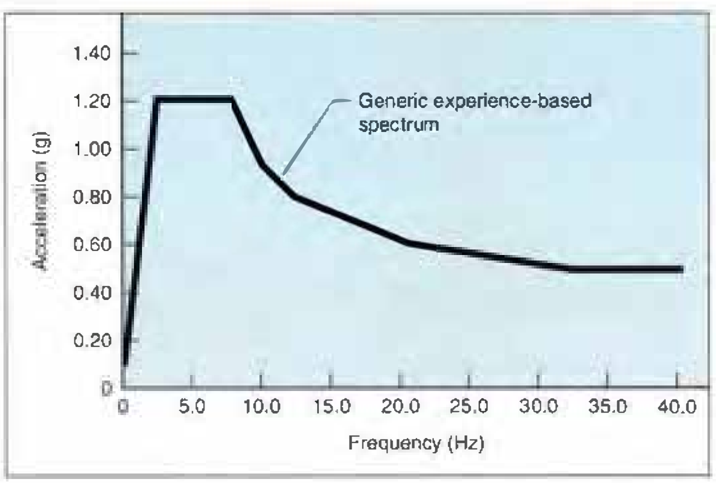


Figure 1 On the basis of data from actual earthquakes, this generic earthquake spectrum has been developed for use in the seismic verification of equipment. The spectrum is a composite that conservatively represents the earthquake motions experienced by the equipment at the database facilities. It serves as the lower bound of the seismic capacity of similar equipment in nuclear power plants. (The spectrum is plotted at 5% damping.)

Applications

Management guidelines have been developed to help utilities implement the GIP methodology to resolve USI A-46. These guidelines address budgeting and planning information (obtained from earlier pilot plant seismic reviews), licensing and other considerations, lessons from prior seismic assessments, and other information intended to assist utilities in their plant-specific verification walkdowns. A significant benefit of the GIP methodology is that it can be used in the future for the seismic verification of new and replacement equipment in A-46 plants. Thus the management guidelines also provide utilities with information on the actions necessary for revising plant licensing bases to allow the use of the GIP as a substitute for earlier seismic qualification requirements. The guidelines will be updated as lessons are learned and new information is obtained.

Because the seismic verification reviewers (called seismic capability engineers) must exercise considerable judgment in implementing the GIP methodology, they are required to attend training courses. Over the past several years, EPRI and SQUG have developed two such courses. The first covers the identification of safe shutdown equipment and the seismic evaluation of electrical relays. It is a three-day course oriented toward systems engineers, who will perform those tasks. The second course covers verification walkdown screening and seismic evaluation. Intended for mechanical and structural engineers, who will perform the evaluations, the course entails a full week of intensive training, including lectures, case studies, and field exercises. A videotape version of the course is being prepared to give utilities an in-house capability for ongoing training. It is expected to be completed this year.

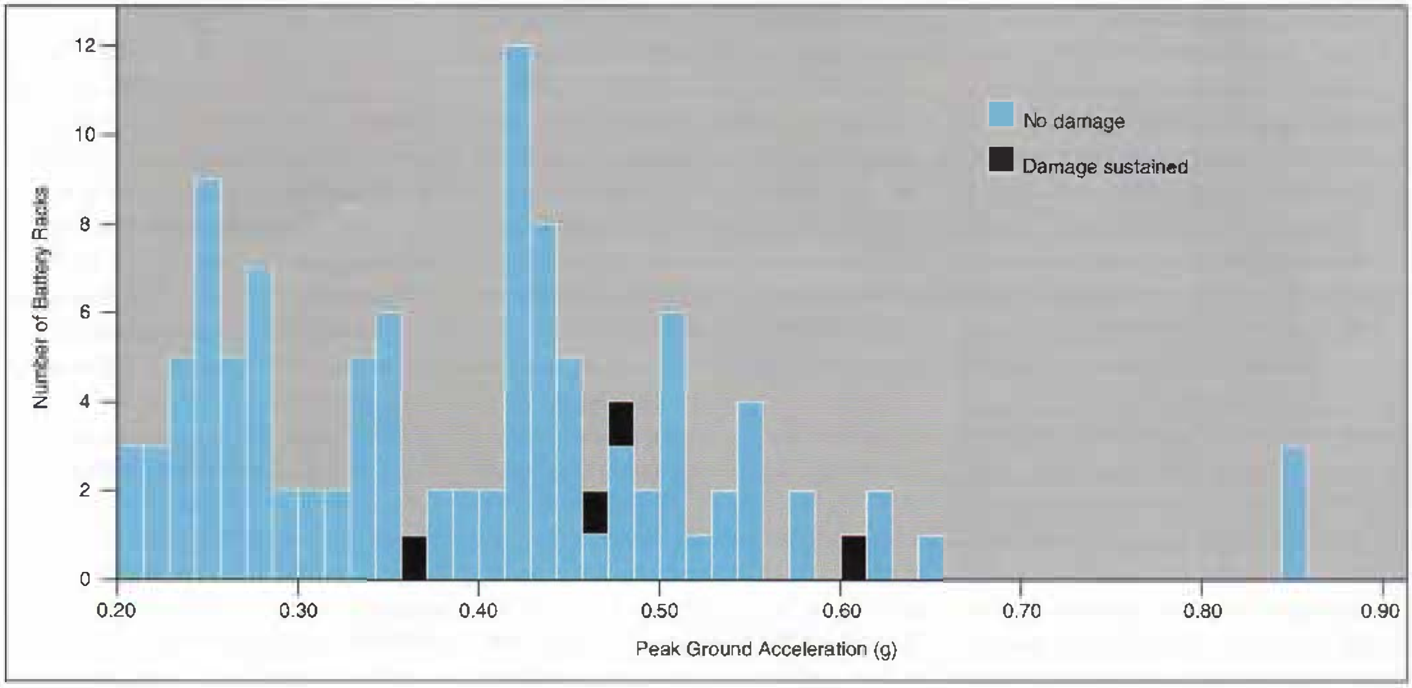
In addition to the A-46 reviews, the NRC is requiring the seismic evaluation of nuclear facilities for earthquakes larger than their design basis. This parallel effort falls under the NRC's IPEEE (individual plant examination for external events) requirement, part of the policy for evaluating the effects of postulated severe accidents. EPRI has developed a seismic margins methodology for performing the IPEEE review. Because this methodology and the GIP are similar, EPRI, SQUG, and the Nuclear Management and Resources Council have cooperated to develop companion training for the utility engineers who will perform the seismic IPEEE for their nuclear units. This training is conducted as a three-day supplement to the verification walkdown training course.

As noted above, an important long-term application of the GIP methodology is the seismic verification of new and replacement equipment in the A-46 plants. The cost benefit of this application was recognized early in the development of the methodology and was acknowledged in the NRC's Generic Letter 87-02, issued in 1987. Since that time, specific conditions for the use of the GIP for new and replacement equipment have been agreed to by the industry and the NRC. The main conditions are as follows:

- Verification walkdowns for equipment not included in the initial A-46 reviews will be completed in accordance with the GIP.
- Plants' licensing bases will be revised, where appropriate, to reflect the GIP criteria.
- The GIP will be maintained as a working document in accordance with a procedure approved by the NRC. This procedure requires peer review of substantive technical revisions and NRC review and approval of all GIP revisions.

Guidelines for applying the GIP to the verification of new

Figure 2 Selected inventory of batteries and racks in the seismic experience database as a function of ground motion. Each bar represents a facility that was surveyed after experiencing seismic motion. In all the earthquakes studied, there were only four cases of loss of function in this equipment class—one resulting from the collapse of a nearby wall (at about 0.35g), one involving internal battery damage (at about 0.45g), and two resulting from a lack of restraints.



and replacement parts have been developed for use by all SQUG members. These guidelines cover the extension of the GIP to systems and equipment outside the initial A-46 review and address how the methodology relates to the EPRI guidelines on the dedication of commercial-grade items. The latter guidelines are contained in the EPRI report *Seismic Technical Evaluation of Replacement Items* (STERI). Together, the STERI guidelines and the GIP extension guidelines cover the full range of plant replacement needs, including like-for-like replacements and replacements that involve design changes or equipment modifications.

It is anticipated that as utilities begin to implement the GIP methodology, they (and the NRC inspectors) will have questions requiring rule interpretation and clarification and will identify problems not now addressed by the GIP. EPRI and SQUG will respond to those needs by providing consistent, informed interpretations and by offering guidance in the areas not covered in the GIP. That process could include the development of new data or criteria, if they are determined to be necessary.

Recognizing the value of interutility communication as the industry addresses USI A-46, the NRC has asked that a mechanism for such communication be developed and implemented. In response, the utilities have agreed that the results of member verification walkdowns will be shared with all other affected utilities. To that end, EPRI will maintain an electronic bulletin board for communicating information, sharing problems and lessons, and disseminating approved interpretations and responses to generic issues. Such an interutility communication system has proved invaluable in similar regulatory-driven programs, and it is expected to be so in this case—not only ensuring consistency of approach and providing direct assistance to SQUG members but also providing a mechanism for generic responses to NRC questions and concerns.

The future

The GIP methodology is based on information from earthquakes and seismic qualification tests. Because earthquakes continue to occur and test data continue to become available, there is a need to review significant new information so that the GIP can be updated and revised when necessary. The GIP will also need to be revised as a result of lessons learned during the early stages of implementation. The NRC recognizes this need and has required that the GIP be so updated.

When new engineering methodologies are technically justified, cost-effective, and accepted by large segments of the industry, codes and standards organizations become interested in codifying those methodologies. That process has begun for the SQUG approach to the seismic verification of equipment. The use of the experience-based approach is recognized in the 1987 version of the Institute of Electrical and Electronics Engineers' Standard 344, the standard currently used by nuclear plant owners for the seismic qualification of both electrical and mechanical equipment. And talks between EPRI, utility representatives, and the American Society of Mechanical Engineers are under way, with the objective of incorporating the GIP into the ASME's new standard for the seismic qualification of mechanical equipment.

New Contracts

Project	Funding / Duration	Contractor / EPRI Project Manager
Customer Systems		
1992 Innovative Rate Survey: Update (RP2343-11)	$83,300 13 months	CSA Energy Consultants / *P. Sioshansi*
Characterization of Energy Storage for Transportation (RP2415-31)	$93,700 5 months	Bechtel Group / *P. Symons*
Development of Software for the Economic Analysis of Medical Waste Disposal Options (RP2662-41)	$50,200 7 months	Wenatchi Group / *M. Jones*
Development and Demonstration of Energy Management Control Strategies for Automated Real-Time Pricing (RP2830-15)	$1,429,000 35 months	Honeywell / *L. Carmichael*
Advanced High-Power Uninterruptible Power Supply Systems (RP2918-26)	$78,500 9 months	University of Wisconsin, Madison / *B. Banerjee*
Development of Automatic Generation Control System and Identification of Other Power Quality Improvements (RP2935-20)	$338,000 36 months	Purdue Research Foundation / *M. Samotyj*
Development of End-Use Load Shapes for Hoosier Energy (RP2980-18)	$60,000 9 months	ICF Technology / *R. Gillman*
Development of Rate Advisor Software (RP2982-16)	$77,200 7 months	Electric Power Software / *P. Sioshansi*
Hard-Rock Mining Using a Pulsing Laser (RP3243-6)	$85,200 4 months	International Process Research Corp. / *E. Eckhart*
Development and Maintenance of DSM Evaluation Database (RP3269-16)	$836,300 18 months	Xenergy / *P. Hummel*
Development of DSM Impact Evaluation Monitoring Handbook (RP3269-19)	$86,000 6 months	Fleming Group / *P. Hummel*
Transmission and Distribution Impacts of DSM (RP3337-4)	$74,000 11 months	Energy and Environmental Economics / *G. Heffner*
Fouling in Enhanced Tubes (RP3412-12)	$133,400 27 months	Pennsylvania State University / *W. Krill*
Nonazeotropic Chillers and Heat Pumps (RP3412-13)	$275,000 4 months	Trane Co. / *W. Krill*
Improved Low-Cost Line-Voltage Thermostat (RP3512-8)	$514,000 12 months	Honeywell / *J. Kesselring*
Load Data Analysis Methods and Tools (RP3558-1)	$148,200 14 months	Quantum Consulting / *P. Meagher*
Thermal Storage Energy Use Evaluation (RP3620-1)	$79,200 5 months	Energy Simulation Specialists / *R. Wendland*
Electrical Systems		
Field Trial: TOMCAT 2000 (RP2472-10)	$97,600 8 months	Foster-Miller / *H. Mehta*
Practical Direct Methods for Transient Stability Analysis (RP2473-61)	$298,100 33 months	Cornell University / *G. Cauley*
NERC Backup Control Center Reference Document (RP2473-68)	$50,500 5 months	Macro Corp. / *J. Gralow*
Advanced Power Transformer Demonstration (RP2618-7)	$170,000 36 months	Potomac Electric Power Co. / *S. Lindgren*
Demonstration of Enhanced CRAFT Expert System at a Second Utility Site (RP2944-8)	$50,000 6 months	EPIC Engineering / *J. Gralow*
Database Access Integration Services (DAIS): Product Development and Demonstration, Phase 1 (RP2949-8)	$160,000 7 months	Unisys Corp. / *B. Blair*
Development of Practical Control Center Tools for Power System Restoration (RP3104-2)	$1,072,500 22 months	National Systems & Research Co. / *J. Gralow*
Low-Voltage Secondary Network Cable Reliability Assessment (RP3127-4)	$50,000 10 months	University of Connecticut / *B. Bernstein*

Project	Funding / Duration	Contractor / EPRI Project Manager
Expert Systems in Power System Planning and Engineering: Transient Stability Input and Output Data Analyses (RP3128-1)	$571,000 17 months	ABB Systems Control Co. / *R. Adapa*
State Estimation Issues: Inter-Control Center Data Exchange (RP3355-2)	$183,600 21 months	ECC / *J. Gralow*
Effects of Transient Voltage on Power Devices (RP3389-4)	$69,500 19 months	Tennessee Technological University / *H. Mehta*
Transient Behavior of Systems Containing FACTS Devices (RP4000-50)	$135,100 37 months	University of Waterloo / *R. Adapa*
Electromagnetic Horizontal-Boring Tracking and Guidance Electronics System for Power Cable Installation (RP7910-14)	$225,800 7 months	Maurer Engineering / *T. Rodenbaugh*
Field Testing of the AccuNav Guidance System for Underground Cable Installation (RP7910-15)	$497,700 14 months	Maurer Engineering / *T. Kendrew*
AccuNav II Guidance System (RP7910-16)	$106,400 11 months	Underground Research / *T. Kendrew*
Environment		
Real-Time Monitor for Air Toxics (Metals) in Fossil Plant Emissions (RP1260-56)	$59,900 11 months	SRI International / *B. Toole-O'Neil*
Guidelines for Flue Gas Flow Rate Monitoring (RP1961-13)	$352,700 11 months	Fossil Energy Research Corp. / *E. Petrill*
Risk Communication Evaluation: Focusing on the Reader's Needs (RP2955-10)	$50,400 21 months	University of Pittsburgh / *A. Thrall*
Ecological Models for Integrated Assessment (RP3041-11)	$60,500 26 months	Carnegie Mellon University / *L. Pitelka*
Investigation of Lightweight High-Volume Fly Ash Concretes (RP3176-12)	$186,400 32 months	Radian Canada / *D. Golden*
PISCES Field Testing at Duke Power's Belews Creek and Marshall Stations (RP3177-7)	$600,000 12 months	Radian Corp. / *P. Chu*
Technical Support for PISCES Field Testing (RP3177-8)	$73,800 9 months	Systems Applications / *W. Chow*
PISCES Field Chemical Emissions Monitoring (RP3177-9)	$1,680,300 15 months	Radian Corp. / *P. Chu*
PISCES Field Chemical Emissions Monitoring at Florida Power & Light's Fort Meyers Plant (RP3177-13)	$203,000 2 months	Carnot / *P. Chu*
System Modifications for Copromotion Study in Mice (RP3349-4)	$160,800 1 month	Battelle Memorial Institute / *R. Kavet*
Enhanced Air Toxics Control (RP3453-1)	$489,300 23 months	University of North Dakota / *R. Chang*
Air Toxics Measurement With Activated Carbon Injection (RP3453-2)	$81,200 6 months	Chester Environmental / *R. Chang*
Evaluation of Advanced Selective Catalytic Reduction Designs for Natural-Gas- and Fuel-Oil-Fired Utility Boilers (RP3628-1)	$850,000 48 months	Pacific Gas and Electric Co. / *E. Cichanowicz*
Exploratory & Applied Research		
Influence of Implanted Oxygen-Active Additives on the Oxidation of NiAl Alloys (RP2426-44)	$313,800 36 months	Massachusetts Institute of Technology / *J. Stringer*
Creep/Corrosion Behavior of Alloys in Mixed Oxidants (RP2426-57)	$152,500 22 months	Commission of the European Communities / *W. Bakker*
Electrodes for Efficient All-Polymer Secondary Batteries (RP8002-41)	$80,000 11 months	University of Arizona / *F. Kalhammer*
Indirect Electrochemistry Using Ionomer-Coated Electrodes (RP8002-44)	$171,300 28 months	North Carolina State University / *R. Weaver*

Project	Funding/ Duration	Contractor/EPRI Project Manager
Exploratory & Applied Research (cont.)		
Fuels for Electric Power Production via Biomass- or Bioconversion-Based Processes (RP8003-35)	$130,400 6 months	Fluor Daniel/*S. Alpert*
Intelligent Energy Control (RP8004-24)	$150,000 32 months	North Carolina State University/*L. Carmichael*
Hydrothermal and Water Quality Modeling of Hydroelectric Reservoirs (RP8006-18)	$161,300 36 months	Massachusetts Institute of Technology/*J. Maulbetsch*
Fundamental Heat Transfer Mechanisms in Flooded Reactor Cavities (RP8006-32)	$112,900 27 months	University of California, Los Angeles/*M. Merilo*
Crystallizable Polyimides: Electrical Properties and Microstructure Studies (RP8007-13)	$202,000 36 months	Massachusetts Institute of Technology/*B. Bernstein*
Static Pulsed Magnetic Field Effects on Pineal Melatonin Synthesis (RP8011-12)	$155,100 12 months	University of Texas, San Antonio/*R. Kavet*
Sulfidation and Corrosion of Ferrous Alloy: Surface Studies (RP9002-6)	$59,900 11 months	University of North Texas/*J. Stringer*
Generation & Storage		
EPRI-Europe Rotor (RP1403-21)	$250,000 46 months	Siemens/KWU Technik Werkstoffe/*R. Viswanathan*
Development of Gas System Dynamics Modeling Code: DUCSYS (RP2504-12)	$367,800 38 months	PowerGen/*R. Leyse*
High-Efficiency Advanced Aeroderivative Gas Turbines (RP2620-12)	$200,000 14 months	Pacific Gas and Electric Co./*A. Cohn*
Analysis of Converting Existing Power Plants to District Energy Supply (RP2818-10)	$242,000 13 months	Joseph Technology Corp./*E. Petrill*
Technical Support for Fossil Plant Simulation, Controls, and Automation (RP2922-16)	$170,200 8 months	Indus Technologies/*G. Pflasterer*
Gas Turbine Combustion Viewing System: Prototype Testing (RP2985-4)	$51,700 15 months	Operational Services/*W. Piulle*
Displays for Hard-Panel Emulation: Technology Assessment (RP3152-17)	$98,500 4 months	Mitre Corp./*R. Fray*
Feasibility and Assessment Study for FT4000-HAT Gas Turbine Development: HAT Cycle System Economics (RP3251-5)	$650,000 25 months	Fluor Daniel/*N. Holt*
Boiler Tube Failure in Incineration or Cofiring of Municipal Solid Waste or Refuse-Derived Fuel (RP3295-7)	$109,500 21 months	Battelle, Columbus Laboratories/*B. Dooley*
Magnetic-Bearing Fan and Motor Demonstration (RP3319-1)	$630,300 31 months	Empire State Electric Energy Research Corp./*T. McCloskey*
Expert System Instructor and Performance Monitor Workstation for Compact Simulators (RP3384-1)	$619,600 14 months	Power Safety International/*R. Fray*
Demonstration of Fossil Plant Training Simulator Guidelines (RP3384-2)	$2,627,200 128 months	Duke Power Co./*R. Fray*
Displays for Hard-Panel Emulation: Prototyping (RP3384-8)	$194,600 6 months	Mitre Corp./*R. Fray*
Boiler Feedpump Operation and Maintenance: Development of an Interactive Video Training Program (RP3467-1)	$489,400 16 months	Alabama Power Co./*T. McCloskey*
Fossil Plant Maintenance Network Concept Demonstration (RP3485-12)	$100,300 17 months	Automation Technology/*R. Colsher*
Application of EPRI R&D Products to the Kingston Control Diagnostics Project, Phase 1 (RP3499-2)	$1,200,000 31 months	Tennessee Valley Authority/*J. Weiss*
Guidelines for Large-Screen Displays in Fossil Plant Control Rooms (RP3525-1)	$187,300 6 months	Mitre Corp./*R. Fray*
Application of Creep-FatiguePro System to Montrose Plant (RP3548-1)	$222,300 18 months	Structural Integrity Associates/*D. Broske*
High-Efficiency Advanced Aeroderivative Gas Turbines (RP3587-1)	$600,000 14 months	Pacific Gas and Electric Co./*A. Cohn*
Extending Superheater Longevity by Steam Flow Redistribution (RP3594-1)	$763,000 16 months	Aptech Engineering Services/*R. Tilley*

Project	Funding/ Duration	Contractor/EPRI Project Manager
Integrated Energy Systems		
Strategic Asset Management Case Study (RP3026-6)	$265,700 6 months	Strategic Decisions Group/*L. Rubin*
FACTS Market Assessment (RP3436-3)	$105,400 6 months	Arthur D. Little/*V. Longo*
MIT Joint Program: Integrated Framework for Analysis of Climate Change (RP3441-4)	$335,500 15 months	Massachusetts Institute of Technology/*L. Williams*
POWERCOACH: Implementation and Commercialization (RP3581-2)	$85,200 13 months	Decision Systems International/*R. Siddiqi*
Nuclear Power		
Ultrasonic Modeling (RP2687-12)	$79,900 3 months	Iowa State University/*M. Avioli*
Ultrasonic Wave Propagation in BWR Nozzles (RP2687-13)	$68,500 2 months	Weidlinger Associates/*M. Avioli*
Field Experience With Stress Corrosion Cracking Remedies: Programmatic Support and Fact Finding (RP2812-15)	$141,700 15 months	Dominion Engineering/*A. McIlree*
Assessment of Remedial Measures for Primary Water Stress Corrosion Cracking (RP2812-16)	$68,000 14 months	S. Levy/*A. McIlree*
Investigation of Lead as Cause of Intergranular Attack at Tube-Support Plate Intersections (RP2812-17)	$224,500 16 months	Babcock & Wilcox Co./*A. McIlree*
Probabilistic Evaluation of Piping Seismic Margin and Low-Cycle Fatigue Failure (RP2967-4)	$66,800 13 months	Stevenson & Associates/*H. Tang*
Analytical Support for MAAP 4.0 Development (RP3130-4)	$89,500 7 months	Anatech Research Corp./*E. Fuller*
Radiation Dose Assessment Software to Expand MAAP 4.0 Capabilities (RP3131-9)	$125,000 12 months	Fauske & Associates/*J. Chao*
Development of Mild-Environment Motor Insulation Specification Guideline (RP3186-15)	$84,300 14 months	Strategic Technology and Resources/*F. Rosch*
Development of Procedures for PWR Full-System Decontamination (RP3307-4)	$919,100 23 months	Westinghouse Electric Corp./*C. Wood*
Development of Requirements and Design Concepts for Plant Integrated Workstations (RP3351-3)	$76,300 15 months	MPR Associates/*J. Naser*
EPRI Instrumentation and Control Initiative: Verification and Validation Technology Transfer (RP3352-3)	$94,500 4 months	S. Levy/*S. Bhatt*
Automated Fire Risk Analysis (RP3385-3)	$120,200 11 months	Science Applications International Corp./*R. Oehlberg*
Software Tools for Integrated Assessment of Operator Actions During Accidents (RP3394-2)	$285,000 16 months	S. Levy/*A. Singh*
Programmable Logic Controllers for BWR Systems (RP3406-5)	$139,700 16 months	S. Levy/*J. Naser*
CHECWORKS Demonstration (RP4114-14)	$395,200 5 months	Altos Engineering Applications/*R. Mahini*
Nuclear Safety Workstation Study (RP4114-15)	$149,900 4 months	Altos Engineering Applications/*R. Mahini*
Evaluation of Corrosion-Assisted Cracking of BWR Vessel Attachments (RPC102-15)	$69,700 5 months	Structural Integrity Associates/*R. Pathania*
Application of Guidelines on Commercial-Grade Items to Nuclear Industry Procurement Issues (RPQ101-43)	$104,400 13 months	Cygna Energy Services/*T. Mulford*
Guidelines for the Use of Items Manufactured to Other Industry Standards (RPQ101-44)	$174,100 13 months	Sargent & Lundy/*T. Mulford*
Ultrasonic Technology for Steam Generator Tube Inspection (RPS404-39)	$54,200 16 months	Illinois Institute of Technology/*M. Behravesh*
Crystal River Unit 3 Steam Generator Tube Sections (RPS413-6)	$281,700 7 months	Babcock & Wilcox Co./*P. Paine*

New Technical Reports

Requests for copies of reports should be directed to the EPRI Distribution Center, 207 Coggins Drive, P.O. Box 23205, Pleasant Hill, California 94523; (510) 934-4212. There is no charge for reports requested by EPRI member utilities. Reports will be provided to others for the appropriate payment under the terms of a license agreement.

CUSTOMER SYSTEMS

Survey and Forecast of Marketplace Supply and Demand for Energy-Efficient Lighting Products
TR-100288 Final Report (RP2418-9); $200
Contractors: Lighting Research Institute; Plexus Research, Inc.
EPRI Project Manager: K. Johnson

Assessment and Evaluation of Supermarket Refrigeration in the State of New York
TR-100357 Final Report (RP2569-13); $200
Contractor: Foster-Miller, Inc.
EPRI Project Manager: M. Khattar

Evaluation of Electric Vehicle Battery Systems Through In-Vehicle Testing: Seventh Annual Report (1991)
TR-100975 Final Report (RP3271-2); $200
Contractor: Electrotek Concepts, Inc.
EPRI Project Manager: R. Swaroop

Desalination Technology Evaluation
TR-101019 Final Report (RP2662-23); $200
Contractor: General Atomics International Services Corp.
EPRI Project Manager: M. Jones

Proceedings: International Electric Research Exchange (IERE) Workshop on Electric Vehicles, Advanced Batteries, and Impacts on Electric Utilities
TR-101138 Proceedings; $200
EPRI Project Managers: J. Guy, L. O'Connell

Pinch Technology/Process Optimization, Vol. 1: Case Studies—Multiple Plants
TR-101147 Final Report (RP2783-12, -15); Vol. 1, $200
Contractors: Linnhoff March, Inc.; TENSA Services, Inc.
EPRI Project Manager: A. Amarnath

Pinch Technology/Process Optimization, Vol. 2: Case Study—Steuben Foods, Inc.
TR-101147 Final Report (RP2783-17); Vol. 2, $200
Contractor: TENSA Services, Inc.
EPRI Project Manager: A. Amarnath

Pinch Technology/Process Optimization, Vol. 3: Case Study—Port Townsend Paper Corp.
TR-101147 Final Report (RP2783-19); Vol. 3, $200
Contractor: Linnhoff March, Inc.
EPRI Project Manager: A. Amarnath

Pinch Technology/Process Optimization, Vol. 4: Case Study—Abbott Laboratories, Inc.
TR-101147 Final Report (RP2783-17); Vol. 4, $200
Contractor: TENSA Services, Inc.
EPRI Project Manager: A. Amarnath

Residential High-Efficiency Lighting: An Assessment of Utility Programs
TR-101221 Final Report (RP2597-28); $200
Contractor: Aspen Systems Corp.
EPRI Project Manager: J. Kesselring

Desalination Study of Florida Power & Light Power Plants
TR-101236 Final Report (RP2662-23); $200
Contractor: General Atomics International Services Corp.
EPRI Project Manager: M. Jones

Proceedings: First International Conference on Power Quality—End-Use Applications and Perspectives
TR-101260 Proceedings (RP2935-1); $200
Contractors: Société des Electriciens et des Electroniciens; Hans B. Püttgen; CK & Associates
EPRI Project Manager: M. Samotyj

Assessment of Electric Motor Technology: Present Status, Future Trends, and R&D Needs
TR-101264 Final Report (RP3087-1); $200
Contractor: McCleer Power, Inc.
EPRI Project Manager: B. Banerjee

Medium-Temperature Supermarket Refrigeration Conversion From CFC-12 to HCFC-22 (R-12 to R-22)
TR-101265 Final Report (RP2569-6); $200
Contractor: Foster-Miller, Inc.
EPRI Project Manager: M. Khattar

Proceedings: Advanced Motors and Drives R&D Planning Forum
TR-101288 Proceedings (RP3087-1); $200
Contractor: McCleer Power, Inc.
EPRI Project Manager: B. Banerjee

Manufacturing Issues in the Mass Production of Advanced Electric Motors
TR-101289 Final Report (RP3087-3); $200
Contractor: University of Tennessee, Knoxville
EPRI Project Manager: B. Banerjee

Fundamentals of Electric Power Conversion, Vol. 1: Operating Characteristics and Testing of AC Induction Motors
TR-101290 Final Report (RP3087-5); Vol. 1, $200
Contractor: Stephen D. Umans
EPRI Project Manager: B. Banerjee

Fundamentals of Electric Power Conversion, Vol. 2: Energy-Efficient Polyphase AC Induction Motors
TR-101290 Final Report (RP3087-5); Vol. 2, $200
Contractor: Stephen D. Umans
EPRI Project Manager: B. Banerjee

Status and Trend Assessment of Advanced Battery Charging Technologies
TR-101322 Final Report (RP2918-12); $200
Contractor: San Jose State University
EPRI Project Manager: B. Banerjee

ELECTRICAL SYSTEMS

Experimental Study of Drained Behavior of Drilled Shafts During Static Inclined Loading
TR-101131 Final Report (RP1493-4); $200
Contractor: Cornell University
EPRI Project Manager: M. McCafferty

Intelligent Alarm Processing
TR-101576 Final Report (RP2944-4); $200
Contractor: ECC, Inc.
EPRI Project Manager: R. Adapa

Long-Term Dynamic Simulation: Nuclear and Thermal Power Plant Models (Joint EPRI/CRIEPI Study)
TR-101765 Final Report (RP3144-1); license required
Contractors: Ontario Hydro; Central Research Institute of Electric Power Industry
EPRI Project Managers: N. Balu, P. Hirsch, M. Lauby

ENVIRONMENT

Power Line Calculator for Windows™
TR-101408 Interim Report (RP2966-7); $200
Contractor: Enertech Consultants
EPRI Project Managers: S. Sussman, R. Kavet

Gas Cofiring for Coal-Fired Utility Boilers
TR-101512 Final Report (RP2916-16); $200
Contractors: SFA Pacific, Inc.; Electric Power Technologies, Inc.
EPRI Project Managers: D. Eskinazi, G. Bullock, A. Mehta

Uptake, Translocation, and Accumulation of Polycyclic Aromatic Hydrocarbons in Vegetation
TR-101651 Interim Report (RP2879-10); $200
Contractor: Oak Ridge National Laboratory
EPRI Project Manager: J. Goodrich-Mahoney

Institutional Constraints to Coal Fly Ash Use in Construction
TR-101686 Final Report (RP3176-4); $200
Contractor: GAI Consultants, Inc.
EPRI Project Manager: D. Golden

Electric and Magnetic Field Exposure, Chemical Exposure, and Leukemia Risk in "Electrical" Occupations
TR-101723 Final Report (RP799-27); $200
Contractor: University of Southern California
EPRI Project Manager: L. Kheifets

Flue Gas Desulfurization Cycling Guidelines, Vols. 1 and 2
TR-101730 Final Report (RP1184-30); Vols. 1 and 2, $500 for set
Contractor: Sargent & Lundy
EPRI Project Manager: P. Radcliffe

Proceedings: Tenth International Ash Use Symposium, Vols. 1 and 2
TR-101774 Proceedings (RP3176); Vols. 1 and 2, $200 each volume
Contractor: American Coal Ash Association
EPRI Project Manager: D. Golden

RESICALC: Magnetic Field Modeling Program
TR-101776 Interim Report (RP2966-7); $200
Contractor: Enertech Consultants
EPRI Project Managers: R. Kavet, S. Sussman

EXPLORATORY & APPLIED RESEARCH

Energy Applications of High-Temperature Superconductors: Progress Report
TR-101635 Special Report (RP8009-26); $200
EPRI Project Managers: T. Schneider, D. Von Dollen

Materials Testing in a Gas Turbine Operating on Coal-Derived Gas
TR-101642 Final Report (RP2525-2); $200
Contractor: Rolls-Royce Industrial & Marine Gas Turbines, Ltd.
EPRI Project Managers: W. Bakker, M. Epstein

Superheater Corrosion in Plants Burning High-Chlorine Coals
TR-101729 Final Report (RP1403-28); $200
Contractor: National Power PLC
EPRI Project Manager: W. Bakker

GENERATION & STORAGE

Reducing the Moisture Content of Clean Coals, Vol. 2: High-G Solid-Bowl Centrifuge
CS-5869 Final Report (RP1400-23); Vol. 2, $200
Contractors: Kaiser Engineers, Inc.; Science Applications International Corp.; CQ Inc.
EPRI Project Manager: D. O'Connor

Reducing the Moisture Content of Clean Coals, Vol. 3: Belt Filter Press
CS-5869 Final Report (RP1400-23); Vol. 3, $200
Contractor: CQ Inc.
EPRI Project Manager: D. O'Connor

Reducing the Moisture Content of Clean Coals, Vol. 4: Aiding the Dewatering and Classifying of Fine Coal With an Ultrasonic Tray
CS-5869 Final Report (RP1400-23); Vol. 4, $200
Contractor: CQ Inc.
EPRI Project Manager: D. O'Connor

Monitoring Cycle Water Chemistry in Fossil Plants, Vol. 2
GS-7556 Final Report (RP2712-3); Vol. 2, $200
Contractor: Sargent & Lundy
EPRI Project Manager: B. Dooley

Proceedings: Coal-Handling Systems—The State of the Future II
TR-100828 Proceedings (RP1400-20); $200
Contractor: CQ Inc.
EPRI Project Manager: D. O'Connor

Properties of Pressurized Fluidized-Bed Combustion (PFBC) Ashes
TR-101209 Final Report (RP1336-5); $200
Contractor: Calvert Environmental, Inc.
EPRI Project Managers: O. Tassicker, R. Brown

Demonstration of a Tier Filter Module
TR-101210 Final Report (RP1336-5); $200
Contractor: Calvert Environmental, Inc.
EPRI Project Managers: O. Tassicker, R. Brown

CG-DAMS: Concrete Gravity Dam Stability Analysis Software (Applications Manual)
TR-101665 Final Report (RP2917-12); $200
Contractor: Anatech Research Corp.
EPRI Project Manager: D. Morris

Uplift Pressures in Cracks in Concrete Gravity Dams: An Experimental Study, Vol. 8
TR-101672 Final Report (RP2917-7); Vol. 8, $200
Contractor: University of Colorado
EPRI Project Manager: D. Morris

Evaluation of the Eicher Screen at Elwha Dam: 1990 and 1991 Test Results
TR-101704 Final Report (RP2694-1); $200
Contractor: Stone & Webster Environmental Services
EPRI Project Managers: C. Sullivan, J. Mattice

Proceedings: 1991 Fossil Power Plant Construction Conference
TR-101717 Proceedings; $200
EPRI Project Manager: S. Pace

History of First U.S. Compressed-Air Energy Storage (CAES) Plant (110 MW, 26 h), Vol. 1: Early CAES Development
TR-101751 Final Report (RP2894-1); Vol. 1, $200
EPRI Project Manager: R. Pollak

Proceedings: Second International Conference on Compressed-Air Energy Storage
TR-101770 Proceedings (RP1084-99); $200
Contractor: Accord Services, Inc.
EPRI Project Manager: B. Mehta

High-Temperature Fireside Corrosion Monitoring in the Superheater Section of a Pulverized-Coal-Fired Boiler
TR-101799 Final Report (RP1403-48); $200
Contractor: CAPCIS MARCH, Ltd.
EPRI Project Manager: W. Bakker

Magnetohydrodynamics (MHD) Technology Conceptual Design for MHD Retrofit
TR-101822 Final Report (RP2466-11); $200
Contractor: MHD Development Corp.
EPRI Project Manager: A. Cohn

Refrigeration-Type Cooling of Inlet Air for Public Service Electric & Gas Essex Unit 9
TR-101823 Final Report (RP2221-21); $200
Contractor: Joseph Technology Corp.
EPRI Project Manager: A. Cohn

Assessment of Seam-Welded Steel Piping in Fossil Power Plants
TR-101835 Final Report (RP2596-11); $200
Contractor: Battelle
EPRI Project Manager: R. Viswanathan

INTEGRATED ENERGY SYSTEMS

Powder River Basin Coal Supply and Suitability (EPRI Report Series on Low-Sulfur Coal Supplies)
IE-7119 Final Report (RP3199-8); $100
Contractor: Energy Ventures Analysis, Inc.
EPRI Project Manager: J. Platt

Designing an Integrated Menu of Electric Service Options: Modeling Customer Demand for Priority Service Using C-VALU—Niagara Mohawk Application
TR-100523 Final Report (RP2801); $200
Contractor: Laurits R. Christensen Associates, Inc.
EPRI Project Manager: R. Siddiqi

Engineering and Economic Evaluation of Central-Station Photovoltaic Power Plants
TR-101255 Final Report (RP3166-1, RP3273-3); $200
Contractor: Bechtel Group, Inc.
EPRI Project Manager: C. McGowin

NUCLEAR POWER

PWR Steam Generator Examination Guidelines, Rev. 3
NP-6201, Rev. 3, Final Report (RPS404); $10,000
EPRI Project Manager: M. Behravesh

Circuit Breaker Maintenance, Vol. 1, Part 3: Low-Voltage Circuit Breakers, Westinghouse DB Models
NP-7410 Final Report (RP2814-49); Vol. 1, Part 3, $10,800
Contractor: Grove Engineering, Inc.
EPRI Project Manager: J. Sharkey

Stationary Battery Maintenance Guide
TR-100248 Final Report (RP2814-46); $8000
Contractor: Edan Engineering Corp.
EPRI Project Manager: W. Johnson

Interim On-site Storage of Low-Level Waste, Vol. 3, Part 1: Waste Volume Projections and Data Management
TR-100298 Final Report (RP3800); Vol. 3, Part 1, $200
Contractor: D. W. James & Associates
EPRI Project Manager: C. Hornibrook

Evaluation of Flawed Piping Under Dynamic Loading
TR-100424 Special Report (RP1757-73; RP2756-4, -5); $200
Contractors: Robert L. Cloud & Associates, Inc.; Applied Science and Technology
EPRI Project Manager: J. Gilman

Nuclear Power Plant Common Aging Terminology
TR-100844 Final Report (RP2927-7); $200
Contractor: MPR Associates, Inc.
EPRI Project Manager: G. Sliter

Proceedings: 1991 EPRI Workshop on Secondary-Side Intergranular Corrosion Mechanisms
TR-101103 Proceedings (RPS407-7); $2000
Contractor: Dominion Engineering, Inc.
EPRI Project Manager: P. Paine

Digital Signal Processing for Plant Nondestructive Evaluation: A Primer
TR-101253 Topical Report (RP3148-2); license required
EPRI Project Managers: M. Avioli, S. Liu

Using an Ionizable Gas to Troubleshoot Nonshielded Electric Cables
TR-101273 Final Report (RP2614-45); $200
Contractor: University of Connecticut
EPRI Project Manager: G. Sliter

Proceedings: EPRI Steam Turbine and Generator NDE, Life Assessment, and Maintenance Workshop
TR-101333 Proceedings (RP3232-1); $200
EPRI Project Managers: J. O'Brien, T. McCloskey

Plant Process Computer Upgrade Guidelines, Vols. 1–3
TR-101566 Final Report (RP3208-1), Vols. 1 and 2, license required
TR-101566 Proceedings: Vol. 3, $200
Contractor: Science Applications International Corp.
EPRI Project Manager: S. Bhatt

Self-Tuning Control Technology for Nuclear Power Plants
TR-101650 Final Report (RP2686-5); $200
Contractor: Westinghouse Electric Corp
EPRI Project Manager: S. Bhatt

Guidelines for Interim Storage of Low-Level Waste
TR-101669 Final Report (RP3800), $200
EPRI Project Manager: C. Hornibrook

Addendum to Examination of Weld-Overlaid Pipe Joints
TR-101681 Final Report (RP3232-1); call for price
EPRI Project Manager: J. Lance

Evaluation of Fuel Performance During Load Following: On-site Examination of Four Fuel Assemblies After Three Cycles of Irradiation
TR-101701 Interim Report (RP2630-1); license required
Contractor: Electricité de France—SEPTEN
EPRI Project Manager: O. Ozer

Nondestructive Evaluation of BWR Internal Attachment Welds
TR-101760 Interim Report (RPC105-7); $200
Contractor: EPRI Nondestructive Evaluation Center
EPRI Project Manager: S. Liu

Qualification of In-Service Examination of the Yankee Rowe Reactor Pressure Vessel
TR-101761 Final Report (RP3348-1); $200
Contractor: EPRI Nondestructive Evaluation Center
EPRI Project Manager: S. Liu

BWR Water Chemistry Transients During Power Reductions and Shutdowns
TR-101769 Topical Report (RP2946-5), $200
Contractor: NWT Corp.
EPRI Project Manager: D. Cubicciotti

Electromagnetic NDE Guide for Balance-of-Plant Heat Exchangers
TR-101772 Final Report (RP3232-1); call for price
EPRI Project Manager: J. Lance

Zebra Mussel Monitoring and Control Guide
TR-101782 Final Report (RP3052-3); $500
Contractor: Stone & Webster Environmental Services
EPRI Project Manager: R. Edwards

Field Test of ELOMIX Radioactive Waste Treatment Process for Decontamination Solutions
TR-101797 Final Report (RP1329-6); $200
Contractor: Bradtec, Ltd.
EPRI Project Manager: C. Wood

New Computer Software

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AWARE™: Methodology for the Allocation of Water Resources
Version 1.2 (PC-DOS)
Developer: Decision Focus, Inc.
EPRI Project Manager: Chuck Sullivan

CAT Workstation™: Clean Air Technology Workstation
Version 1.0 (PC-DOS)
Developer: Sargent & Lundy
EPRI Project Manager: Richard Rhudy

COOLAID: Thermal Energy Storage/ Demand-Side Planning/Load and Market Research
Version 3.0 (PC-DOS)
Developer: Regional Economic Research
EPRI Project Manager: Ron Wendland

$CQIM_{386}$: Coal Quality Impact Model
Version 1.1 (PC386-OS/2)
Developer: Black & Veatch
EPRI Project Manager: Arun Mehta

CRFLOOD™: Uplift Pressure Distribution and Drain Effectiveness Software
Version 1.0 (PC-DOS)
Developer: University of Colorado
EPRI Project Manager: Doug Morris

Desk Book™: Residential End-Use Technologies
Version 1.0 (PC-Macintosh)
Developer: Aptech Engineering Services, Inc.
EPRI Project Manager: John Kesselring

DYNRED: Dynamic Reduction Program
Version 1.0 (Apollo-AEGIS; DEC-ULTRIX; RS6000-AIX; Sun-UNIX)
Developer: Ontario Hydro
EPRI Project Manager: Peter Hirsch

ETMSP: Extended Transient–Midterm Stability Package
Version 3.0 (Apollo-AEGIS; DEC-ULTRIX, DEC-VMS, Prime-PRIMOS; RS6000-AIX, Sun-UNIX)
Developer: Ontario Hydro
EPRI Project Manager: Neal Balu

GATE/CYCLE: Gas Turbine Evaluation Code
Version 3.41 (PC-DOS)
Developer: Enter Software, Inc.
EPRI Project Manager: Henry Schreiber

ICRS: I&C Requirements and Standards Database
Version 1.0 (PC-DOS)
Developer: MPR Associates
EPRI Project Manager: William Reuland

INFORM: Industrial End-Use Forecasting Model
Version 1.0 (PC-DOS)
Developer: Regional Economic Research
EPRI Project Manager: Phil Hummel

IPFLOW: Interactive Power Flow
Version 1.0 (Apollo-AEGIS)
Developer: Ontario Hydro
EPRI Project Manager: Neal Balu

LDAW: Load Data Analysis Workstation
Version 1.2 (PC-DOS)
Developer: Quantum Consulting
EPRI Project Manager: Paul Meagher

Micro-AXCESS: Building Energy Analysis Program
Version 10.2 (PC-DOS)
Developer: James J. Hirsch & Associates
EPRI Project Manager: Karl Johnson

SARA™: Safety Review Advisor
Version 1.0 (PC-DOS)
Developer: Sargent & Lundy
EPRI Project Manager: William Reuland

SSSP: Small Signal Stability Program
Version 3.0 (Apollo-AEGIS; DEC-ULTRIX; RS6000-AIX; Sun-UNIX)
Developer: Ontario Hydro
EPRI Project Manager: Peter Hirsch

SURIS: DSM Survey Information System
Version 4.0 (PC-DOS)
Developer: Plexis Research, Inc.
EPRI Project Manager: Paul Meagher

TRELSS: Transmission Reliability Evaluation for Large-Scale Systems
Version 1.0 (DEC-VMS)
Developer: Southern Company Services
EPRI Project Manager: Neal Balu

VALOR™: Simulating Immiscible Contaminant Transport in Subsurface Systems
Version 1.0 (PC-DOS)
Developer: University of Michigan
EPRI Project Manager: Dave McIntosh

VSTAB: Voltage Stability
Version 2.1 (DEC-VMS; RS6000-AIX; Sun-UNIX)
Developer: Ontario Hydro
EPRI Project Manager: Neal Balu

EPRI Events

JULY

22–23
Seminar on Management of Low-Level Waste
Boulder, Colorado
Contact: Pam Turner, (415) 855-2010

28–30
PWR Fuel Cladding Corrosion
Washington, D.C.
Contact: Rosa Yang, (415) 855-2481

AUGUST

2–3
Lightning Protection Design Workstation
(member utilities only)
Irving, Texas
Contact: Kathleen Lyons, (415) 855-2656

3–5
Thermography Workshop
Eddystone, Pennsylvania
Contact: Paul Zayicek, (704) 547-6100

16–18
Radiation Field Control
Seattle, Washington
Contact: Linda Nelson, (415) 855-2127

17–19
Steam Generator NDE
Location to be announced
Contact: Ulla Gustafsson, (415) 941-8552

17–19
6th International Workshop on Main Coolant Pumps
Toronto, Ontario
Contact: Rick Sturkey, (704) 547-6043

24–27
EPRI-EPA-DOE 1993 SO_2 Control Symposium
Boston, Massachusetts
Contact: Pam Turner, (415) 855-2010

SEPTEMBER

8–10
EPRI's 9th Electric Utility Forecasting Symposium: Forecasting and DSM
San Diego, California
Contact: Lori Adams, (415) 855-8763

14–17
PCB Seminar
New Orleans, Louisiana
Contact: Linda Nelson, (415) 855-2127

16–17
Operational Reactor Safety Engineering and Review Group Workshop
Baltimore, Maryland
Contact: Susan Bisetti, (415) 855-7919

19–24
In Situ Monitoring of Corrosion and Water Chemistry
Houston, Texas
Contact: Barry Syrett, (415) 855-2956

21–23
4th International Symposium on Biological Processing of Fossil Fuels
Sardinia, Italy
Contact: Stan Yunker, (415) 855-2815

27–October 1
4th International Conference on Batteries for Energy Storage
Berlin, Germany
Contact: Steve Eckroad, (415) 855-1066

29–October 1
Condenser Technology
St. Petersburg, Florida
Contact: Lori Adams, (415) 855-8763

OCTOBER

7–8
Repowering With Gas Turbines
Danvers, Massachusetts
Contact: Barry McDonald, (714) 259-9520

13–15
Fuel Supply Seminar
Tampa, Florida
Contact: Susan Bisetti, (415) 855-7919

19
Air Toxics R&D Results
Pittsburgh, Pennsylvania
Contact: Denise O'Toole, (415) 855-2259

19–21
Fossil Plant NDE
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (215) 595-8871

20
Air Toxics R&D Results
Atlanta, Georgia
Contact: Denise O'Toole, (415) 855-2259

20–22
Meeting Customer Needs With Heat Pumps
New Orleans, Louisiana
Contact: Pam Turner, (415) 855-2010

21
Air Toxics R&D Results
Denver, Colorado
Contact: Denise O'Toole, (415) 855-2259

26–28
Fossil Plant Construction
Palm Beach, Florida
Contact: Lori Adams, (415) 855-8763

27–28
Annual Fuel Oil Utilization Workshop
Baltimore, Maryland
Contact: Stephanie Drees, (714) 259-9520

27–29
12th Coal Gasification Power Plants Conference
San Francisco, California
Contact: Linda Nelson, (415) 855-2127

NOVEMBER

8–11
4th Annual Seminar on Decision Analysis for Utility Planning
San Diego, California
Contact: Katrina Rolfes, (415) 854-7101

9
Low-Level Waste Training Courses
Monterey, California
Contact: Linda Nelson, (415) 855-2127

10–12
International Low-Level Waste Conference
Monterey, California
Contact: Linda Nelson, (415) 855-2127

15–18
International Conference on Fossil Plant Simulators, Modeling, and Training
New Orleans, Louisiana
Contact: Susan Bisetti, (415) 855-7919

19
2d International Seminar on Subchannel Analysis
Palo Alto, California
Contact: Lance Agee, (415) 855-2106

DECEMBER

1–3
2d National Electric Vehicle Infrastructure Conference
Scottsdale, Arizona
Contact: Pam Turner, (415) 855-2010

6–9
4th International Conference on Cold Fusion
Maui, Hawaii
Contact: Linda Nelson, (415) 855-2127

7–9
Predictive Maintenance Workshop
San Francisco, California
Contact: Susan Bisetti, (415) 855-7919

8–9
6th Annual Conference on Utility Strategic Asset Management
St. Petersburg, Florida
Contact: Lori Adams, (415) 855-8763

8–10
Efficient Lighting Symposium
Scottsdale, Arizona
Contact: David Ross, (703) 742-8402

8–10
Expert Systems Applications for the Electric Power Industry
Phoenix, Arizona
Contact: Jouni Keronen, (415) 855-2020

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